6-2003

Treatment of industrial wastewater from food processing plant under climate conditions

Saeed Mohamed Wali Abdulla Karmustaji

Treatment of Industrial Wastewater from Food Processing Plant Under Climate Conditions

by

Saeed Mohamed Wali Abdulla Karmustaji

Thesis submitted to the Faculty of Graduate Studies
United Arab Emirates University
In partial fulfillment for the requirements for the degree of
Master of Science in Water Resources

United Arab Emirates University
Faculty of Graduate Studies
June - 2003

Thesis of Saeed Mohamed Wali Abdulla Karmustaji
Submitted in partial fulfillment for the Degree of
Master of Science in Water Resources

Chair of the Examination Committee
Dr. Ibrahim Ashour ....

Member of the Examination Committee
Dr. Fahmi Abu Al-Rub ....

Member of the Examination Committee
Prof. Vijay P. Singh ....

Dean of the Graduate Studies
Dr. Hadef Rashed Al-Owais ....

United Arab Emirates University
2002/2003

Acknowledgments

I would initially like to thank my first supervisor, Dr. Ibrahim Ashour (Chemical Engineering Department, University of UAE) for his encouragement, help and advice throughout the preparation of this thesis. My deepest gratitude must be given to my co-supervisor Dr. Shaker Ali (General Manager, Rentec Environment Protection Technology, Dubai) for his invaluable assistance and guidance, for without his help this research could not have been possible.

I would also like to thank Dr. Gharib Sayed Ali (Former Director of CLU, University of UAE) and Dr. Saad Shahatta (Director of CLU, University of UAE), and the rest of CLU staff for helping with analyzing the water samples.

Many thanks to the manager and staff of the Seville Products Limited Co., for allowing me on their premises to conduct my sampling and study on their wastewater treatment plant.

Finally, I would like to dedicate this thesis to my family who inspired me and spared me time and patience to complete this research study.

ABSTRACT

This research thesis will study the performance of wastewater treatment plant using a two-phase continuous flow anaerobic / aerobic treatment plant for the treatment of industrial wastewater from a confectionary factory in Dubai. The treatment design is based on anaerobic process under mesophilic (31 +/- 2 ^{0}C) range where only the heat of the inlet and the natural climatic temperature are utilized to maintain the reactor operational. An aerobic activated sludge process to achieve the required legal standards follows the anaerobic treatment.

During the anaerobic process, biogas is generated and stored in a collection chamber and linked to an automated flare system. The sludge is digested aerobically and passed over a belt filter press system for de-watering to a minimum of 25% dry solids content.

In order to accomplish this study, wastewater samples were collected through different stages of treatment and at different seasons to investigate any effects from the climate changes. Samples were analyzed at UAE University's Central Laboratory Unit for VFA, while other parameters, such as BOD, COD, TSS, TDS and oil were analyzed at a private laboratory, approved by Dubai Municipality.

A brief comparison between this two-phase system and a sequential batch reactor (SBR) system is made at the end. Although both systems were used in this case for treatment of food industry waste, the two-phase system has proved more efficient in treating high strength, lower volume wastewater, and required less installation space at lower building and running costs.

The results obtained indicated that the two-phase system under climate conditions is especially suitable for the UAE and Middle East climate, since it depends on the heat of inlet water and atmosphere. No major variations in the treatment were detected, during the 2 years course of study, even though samples were collected at different climate temperatures.

It might appear that the SBR system, which was used to make our comparative study, treated to a better standard. This could be partially true, but if we compare the waste volume and consistency, the influent quality, costs and space involved with the SBR system, the two-phase system served as a much cheaper and as effective alternative for treatment.

Finally, the impact of this research work is expected to be better understanding of wastewater treatment and minimization mechanism, which is a rich field for research and development in the UAE. This could also serve as a basis foe future studies in this field, since no major research has been conducted with regard to this subject in this country.

Table of Contents

List of Symbols

ABR	- Anaerobic Baffled Reactor
AC	- Activated Carbon
AF	- Anaerobic Filter Reactor
AFBR	- Anaerobic Fluidized Bed Reactor
ASBR	- Anaerobic Sequential Batch Reactor
BBO	- Bentonite Bound Oil
BOD_5	- Biochemical Oxygen Demand (5 days)
CLU	- Central laboratory Unit of UAE University
COD	- Chemical Oxygen Demand
CSTR	- Continuously Stirred Tank Reactor
DM	- Dubai Municipality
DSFF	- Down-flow Stationary Fixed Film Reactor
F:M	- Food Microorganism ratio
HLR	- Hydraulic Loading Rate
HRT	- Hydraulic Retention Time
IDL	- Instrument Detection Limit
MB	- Methanogenesis Bacteria
MDL	- Method Detection Limit
MLSS	- Mass Liquor Suspended Solids
N	- Fuzzy Stability Index
O/G	- Oil and Grease
OLR	- Organic Loading Rate
pH	- Acidity or Alkalinity
SBR	- Sequential Batch Reactor
SRB	- Sulfate Reducing Bacteria
TDS	- Total Dissolved Solids
TKN	- Total Kjeldal Nitrogen
TOC	- Total Organic Carbons
TSS	- Total Suspended Solids
UAHB	- Up-flow Anaerobic Hybrid Blanket Reactor
UASB	- Up-flow Anaerobic Sludge Blanket Reactor
VFA	- Volatile Fatty Acids
WAP	- Water Adsorbing Polymer

List of Tables

List of Figures

Chapter 1

Introduction

As the 21st centurey unfolded, many scientists and politicians have had pessimistic views about the future. Future they predicted to be governed by warefare over water and energy rights. From our experience of the Second Gulf War, which is known to many as "Energy War" and the current situation in the Gulf, as well as other water crisis, such as the one between Libanon and Israel over Al Wizzani River, and the disagreement among Turkey, Syria and Iraq over the use of Tigris River waters, we should be concerned about securing and preserving our potable water.

The United Arab Emirates, due to its desert climate and lack of fresh groundwater and surfacewaters, has passed several laws aiming mainly at the protection of marine waters, because of its importance as a source of desalination water and fisheries. The regulations vary from local, such as the Local Order on the Environment Protection Regulations in the Emirate of Dubai which was issued in 1991, to Federal Laws, such as Law No. 25 on Environment Protection and Development which was issued in 1999. Both regulations mandate the treatment of wastewater from domestic and industrial origins before its relaese into any body of the environment, and impose severe punitive measures against violators.

Lately, many government and private sectors are considering the use of water treatment technologies in order to allow recycling of wastewater and reuse for different purposes. Dubai Municipality for instance, uses the treated sewage water to irrigate 100% of the city's landscape. Many private companies operating in the UAE in general and Dubai in specific, that generate a considerable amount of wastewater have provided their own treatment plant in order to comply with government regulation and/or to conserve water.

Wastewater treatment can be carried out under aerobic conditions with aerobic bacteria, or under anaerobic conditions with acidogenic and methnogenic bacteria. Currently, there are many aerobic treatment methods such as: 1) *Lagoons and stabilization basins* that are used for organic wastewater treatment where sufficient land area is available and where groundwater pollution from toxic organics or heavy metals is not an issue; 2) *Aerated lagoons* which are deep basins (8--16 ft) equiped with air diffusers for oxygenation; 3) *Activated sludge process* which converts soluble and insoluble organics in wastewater into microbial suspension that is settleable for separation; 4) *Trickling filters* that are packed beds of media (ususally with plastic) covered with slime growth over which wastewater is passed for organic matter to get removed by biological film; 5) *Rotating bilogical contactor* which is a large-diameter plastic media installed on a horizontal shaft in a tank. The contactor is 40% submerged in wastewater and rotates slowly carrying a film of wastewater through the air, resulting in oxygenation and neutrient transfer with the slime build-ups on the shaft

The anaerobic treatment methods have also evolved to cover different treatment techniques, such as: 1) *Anaerobic filter reactor* which can be operated upflow or downflow accommodates the growth of anaerobic microorganisms on a packing medium, retaining biological solids and allowing solid and gas separation; 2) *Anaerobic contact process* allows the separation and recirculation of seed organisms, and requires a process operation and retention time of 6-12 hours; 3) *Fluidized-bed reactor (FBR)* requires wastewater pumping upward through a sand bed that retains microbial growth, while effluent is recycled for mixing with the feed; 4) *Upflow anaerobic sludge blanket (UASB)* intakes the wastewater from the bottom of the reactor and flows upward through a blanket of biologically formed granules which consumes the waste, raising biogas to the gas dome and liquid is sent for separation; 5) *ADI-BVF process* is a low-rate anaerobic process with intermittent mixing and sludge recycle, and it consists of a reaction zone at the inlet and a clarification zone at the outlet (Eckenfelder, 2000).

The anaerobic process has proved advantageous over aerobic process in treating toxic waste or high load organic wastewater, and yields considerably less sludge, since part of the organic load is converted to biogas. The main advantages of anaerobic treatment process over aerobic process are: 1) Anaerobic treatment has proved more effective in treating high strength and toxic inustrial waste over any aerobic processes; 2) Anaerobic treatment is used as a pretreatment step to aerobic in order to control odors and reduce the cost of final treatment; 3) It usually requires less space, 4) Allows biogas separation which can be used for energy production, as well as reduing the final sludge volume.

The main objective of this thesis is to study the performance of a two-phase treatment plant, operating under climate conditions, in the treatment of wastewater produced from a confictionary plant. The wastewater is generated as a result of washing moulds, utensils, and mixing vessels, and discharged at a rate of 50-150 m^3/d. The plant under study is a two-phase plant that consists of a continuous flow anaerobic treatment plant followed by aerobic (activated sludge) polishing phase. Biogas is collected from the anaerobic phase and flared. The effluent water is currently treated to sewer water standards and tankered to sewage treatment plant for further treatment before use for irrigation. The sludge is 100% organic and is sent to municipal landfill.

Wastewater from different treatment stages is collected and chemically analyzed in UAE University's central laboratory unit. Comparative analysis results were obtained through the company from a private laboratory in Dubai.

In order to provide beneficial references to this study, the second chapter of this paper provides a literature review of many different types of treatment plants treating various types and volumes of waste under different conditions. Furthermore, a description of the wastewatwer treatment plant is presented in chapter 3. While in chapter 4, a comparison is made between our two-phase plant and a sequential batch reactor (SBR) plant treating a food cooking and canning industrial waste in Dubai. Lastly, the main findings and recommendations are presented in Chapter 5.

Chapter 2

Literature Review

2.1 Introduction

Treatment of organically polluted wastewaters has been carried out since the beginning of this century in so-called conventional biological treatment plants. The basis of these plants is the aerobic flocculated active sludge process. Over the past few decades, there has been an enormous expansion of the industrial activity and population density leading to the enhanced use of these conventional processes near large population centers. This development has led to an ever-increasing awareness of the many inherently negative aspects of these conventional processes (Heijnen et al., 1990). Conventional treatment plants have been reported to suffer from the following problems:

- Their large space requirement,
- Emissions into populated environment from large open reactors,
- Low process efficiency,
- Large surplus production and energy consumption,
- Low sludge concentration, and
- Poor sludge settling.

Many researchers have focused their attention on the development of anaerobic industrial wastewater treatment processes to comply with the new regulations and to preserve our environment. Many processes have been covered in the literature (for instance, Metcalf and Eddy, 1991, Barber and Stuckey, 1999, Lapara and Alleman, 1999, Ellis et al., 2002, Grismer et al., 2002). Anaerobic process is one of the oldest processes used for stabilization of sludge and industrial wastewater with high and low organic strength (Riffat et al., 1998, 1999). This process is becoming a proven technology and has gained a lot of considerable importance in the last two decades (Stronach et al., 1986; Fernandez et al., 1995; Switzenbaum, 1995; Hulshoff et al., cited in Punal et al., 2002). Riggle (1996) reported that "in the area of industrial wastewater treatment alone, more than 600 vendor supplied systems are operating or under construction throughout the world: 44% in Europe, 14 % in North America, and a considerable number also in Asia and South America". Anaerobic is used as a pretreatment step, for instance, at municipal wastewater treatment facility to control odor, and reduce the cost of final treatment.

In the anaerobic process, the organic material is converted biologically to a variety of end products, including methane (CH_4) and carbon dioxide (CO_2). The process is carried out in airtight reactor. There are similarities between aerobic and anaerobic systems related to process kinetics and material balances, but certain basic differences require special consideration (Eckenfelder, 2000). The conversion of organic acids to methane gas yields little energy; hence the rate of growth is slow, and the yield of organisms by synthesis is low. The kinetic rate of removal and the sludge yield both are considerably less than in the activated sludge process. Figure (2.1) shows the more common processes now in use.

2.2 Types of Anaerobic Processes

The anaerobic wastewater treatment is completed in two stages: 1) hydrolysis-acidification (acidogenesis), in which organic suspended solids are broken down to volatile fatty acids (VFA) such as acetic, propionic, and butyric acids; and 2) acetogenesis-methanation (methanogenesis), in which VFA is converted to methane gas. These two stages can be carried out in one reactor as a single-phase process, or separated in two reactors as a two-phase process. A study by Borja and Banks (1995) on single-phase and two phase anaerobic reactors treating ice-cream manufacturing wastewater concluded that separating the degradation phases can improve the process performance, increase biogas yield, and achieve better system stability.

In the above study, during experimentation of the two-phase reactor, the hydraulic retention time (HRT) for acidification phase was 0.3 day and its

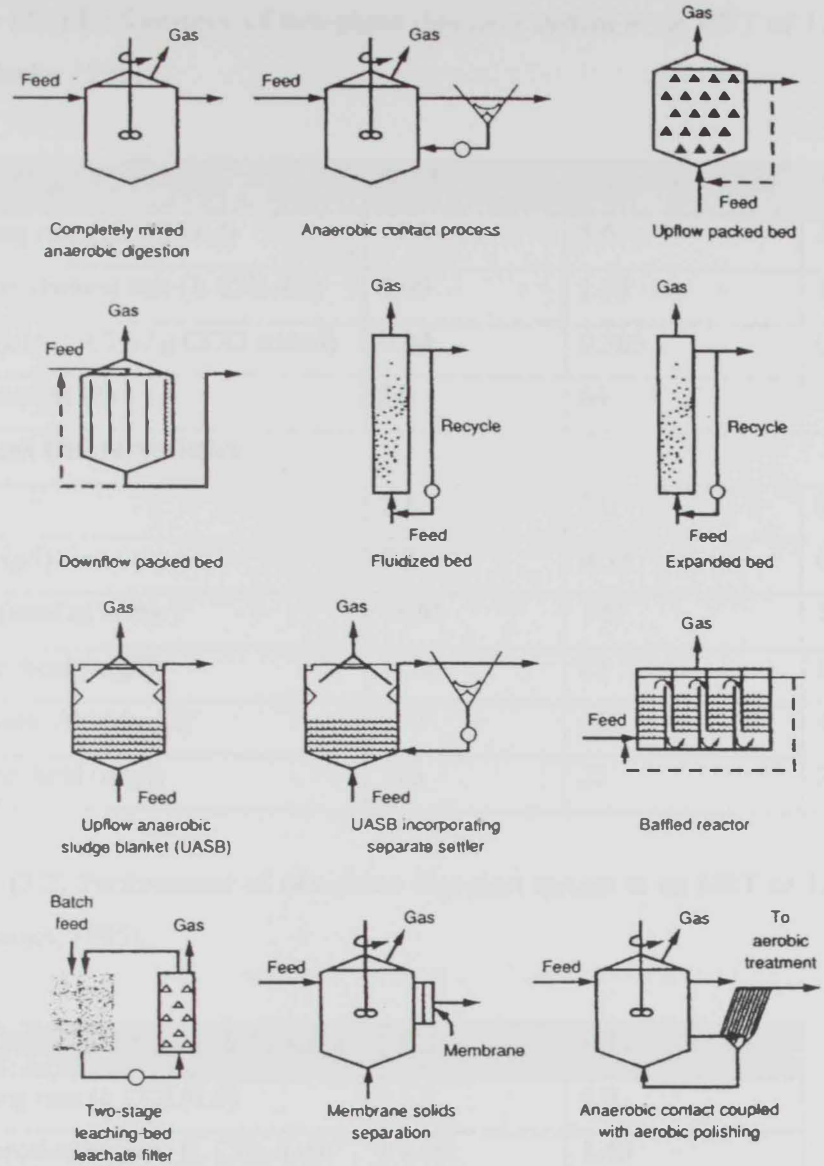


Figure 2.1 Typical reactor configurations used in anaerobic wastewater treatment (Speece, 1983, cited in Metcalf and Eddy 1991)

effluent used to maintain the methanogenesis phase at an HRT of 1day. Once per day, each reactor was thoroughly mixed and allowed to settle before feeding the reactor again. The results obtained for the two-phase system are shown in Table (2.1). For one phase digestion system, the operational HRT was 1 and 1.3 days at 35°C, and using the batch feed system identical to that for the two-phase system. The results of this experiment are shown in Table (2.2).

Table (2.1) Performance of two-phase digestion system at an HRT of 1.3 days (Borja and Banks, 1995).

Operating Conditions	Acid Phase	Methane Phase	Total System
Loading rate (g COD/Ld)	17.3	5.0	4.0
CH_4 production rate (L CH_4 /Ld)	0.69	1.53	1.02
CH_4 yield (L CH_4 / g COD added)	0.04	0.305	0.345
CH_4 content (%)	34	64	
Effluent Characteristics:			
PH	5.1	7.0	7.0
COD (g/l)	5.0	0.55	0.55
VFA (total as acetic)	1820	140	140
Acetic Acid (mg/l)	1150	85	85
Propionic Acid (mg/l)	550	45	45
Butyric Acid (mg/l)	275	25	25

Table (2.2) Performance of one-phase digestion system at an HRT of 1.3 days (Borja and Banks, 1995).

Operating Conditions & Results	1 d	1.3 d
Loading rate (g COD/Ld)	5.2	4.0
CH_4 production rate (L CH_4 /Ld)	1.06	1.40
CH_4 yield (L CH_4 / g COD added)	0.205	0.305
CH_4 content (%)	60	61
Effluent Characteristics:		
PH	6.9	7.1
COD (g/l)	0.65	0.45
VFA (total as acetic)	205	130
Acetic Acid (mg/l)	105	70
Propionic Acid (mg/l)	85	45
Butyric Acid (mg/l)	45	20

Two – phase systems are especially suitable for wastewaters with high concentrations of organic suspended solids, since they could be degraded to Volatile Fatty Acids (VFA) in the first reactor by hydrolytic and acidogenic bacteria and finally converted into methane in the second reactor (Mata-Alvarez, 1987). The final distribution of the VFA generated depends mainly on the nature of the substrate and the operational conditions, especially pH (Breure et al., 1984; Breure and Van Andel, 1984).

Other studies (for instance, Dinopoulou et al., 1988; Alexiou et al., 1994; Speece, 1996, Azbar and Speece, 2001) have been conducted on single and two phase anaerobic reactors treating wastewater from food industries with high contents of organic solids and protein discovered several advantages of the two-phase process over single-phase process, such as: i) better control of both acidogenesis and methanogenesis steps, ii) smaller reactor size, iii) higher SS removal efficiency, iv) enhancement of acidogenesis microorganisms growth without the disruption of methanogens, v) higher methanogenesis specific activity in the second reactor, and vi) the ability to remove toxic substances for methanogens formed in the acidogenesis phase by inserting an intermediate step.

The disadvantages of a two-stage process are higher investment for building a second reactor, and poor granule formation in methanogenesis sludge bed reactors treating acidified wastewater (Guerrero, et al., 1999).

2.3 Process Microbiology

Eckenfelder (2000) reported that in anaerobic fermentation, roughly four of microorganisms sequentially degrade organic matter. First, hydrolytic microorganisms degrade polymer type material such as proteins and polysaccharides to monomers. This reduction results in no reduction of COD. These monomers are then converted into volatile fatty acids (VFA), for instance, acetic, propionic, butyric, valeric, with small amount of hydrogen. Second, acetogenic microorganisms convert all acids higher than acetic acid into acetic acid and hydrogen. The conversion of propionic acid is:

$$C_3H_6O_2 + 2H_2O \rightarrow C_2H_4O_2 + CO_2 + 3H_2$$

Methanogenic organisms convert acetic acid and hydrogen into methane.

$$\text{Acetic acid}: \quad C_2H_4O_2 \rightarrow CO_2 + CH_4$$

$$CH_3COO^- + H_2O \rightarrow CH_4 + HCO_3^-$$

$$\text{Hydrogen}: \; HCO_3^- + 4H_2 \rightarrow CH_4 + OH^- + 2H_2O$$

Figure (2.2) demonstrates the three stages of methane fermentation. There are two methanogens that convert acetate to methane, namely Methanothrix, and Methanosarcina. Speece (1996, cited in Eckenfelder, 2000) has reported that if traces of nutrients, for instance, iron, cobalt, nickel, etc, are available in highly loaded systems, Methanosarcina will predominate, with higher specific activity, 3 to 5 times as high as Methanothrix, and for a low steady state acetate concentration Methanothrix will predominate. The dominance of scavenging bacteria such as Methanosaeta was experienced with treatment of low strength wastewater in anaerobic baffled reactor (ABR). Barber and Stuckey (1999) concluded that no significant change was found in the population of acid producing bacteria down the length of a reactor treating dilute milk, which is an indication of low population selection of bacteria at low COD concentrations.

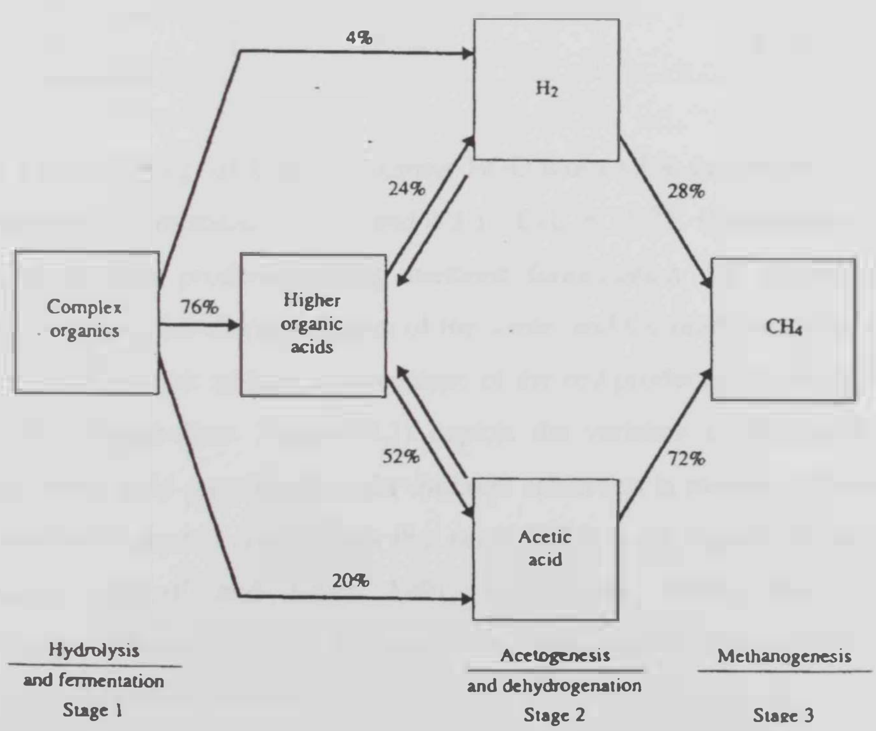


Figure 2.2 Three stages of methane fermentation (Eckenfelder, 2000)

Zehnder et al. (1982, cited in Eckenfelder, 2000) found that the optimal methanogen growth and the specific rate of methane production required between 0.001 and 1 mg/l sulfur as S. The kinetic relationship commonly employed for anaerobic degradation is the Monod relationship:

$$\frac{dS}{dt} = \frac{k_{max} SX}{K_S + S} \tag{2.1}$$

where dS/dt = substrate utilization rate, mg/(l.d),

k_{max} = maximum specific substrate utilization rate, g COD/(g VSS .d),

S = effluent concentration, mg/l,

X = biomass concentration, mg/l,

K_S = half saturation concentration, mg/l

Typical values for the coefficients in anaerobic systems (Eckenfelder, 2000)

Temperature, ^{O}C	K_{max}, d^{-1}	K_S, mg/l
35	6.67	164
25	4.65	930
20	3.85	2130

For every 1 lb (0.454 kg) of COD or ultimate BOD removed in the process will yield 5.62 ft^3 (0.16 m^3) of methane at 0 ^{O}C and 6.3 ft^3 CH_4 at 35 ^{O}C (Eckenfelder, 2000). The quantity of cells produced during methane fermentation will depend on the strength of the waste, the characterization of the waste, and the retention of the cells in the system. As in aerobic system, a percentage of the cell produced will be destroyed by endogenous metabolism. Figure (2.3) depicts the variation of biological solids production versus solid retention time for different substrates in methane fermentation process. Similar to aerobic relationships that presented in many papers and textbooks (for instance, Metcalf and Eddy, 1991, Eckenfelder, 2000), the following relationships, that obtained by McCarty and Vath (1962, cited in Eckenfelder, 2000), are used for the anaerobic process:

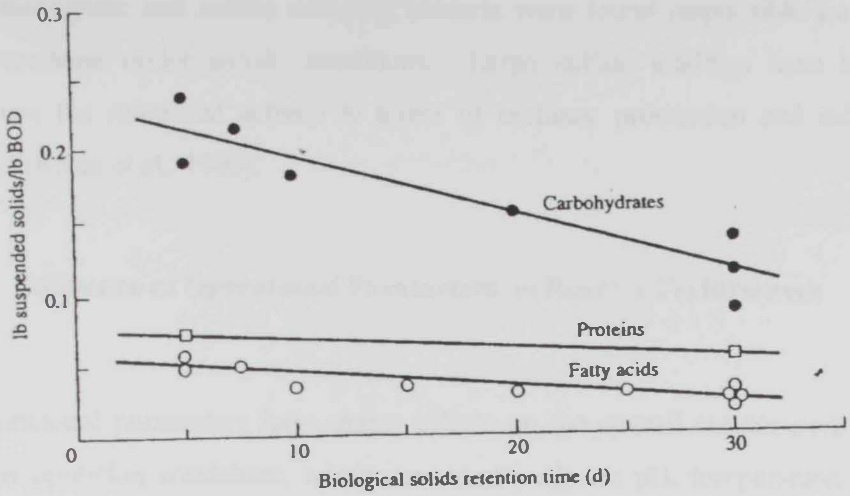


Figure 2.3 Biological solids production resulting from methane fermentation (Eckenfelder, 2000)

2.3.1 Microbial Strain Isolation

The study by Ishino et al. (1998) of methanogeneic archaeon bacteria revealed that the organism has only one DNA polymearse gene. Studies also demonstrated that methanogenesis involve common genes. Westlund et al. (1998) identified the filamentous organism *Microthrix parvicella* as a causative agent of foaming in anaerobic digesters. Thirteen different species of bacteria were identified, when the formation of biofilm and temporal change in bacterial composition at different sugar concentrations was conducted in an anaerobic fluidized bed reactor. Strains of *Acinetobacter* isolated from treatment plants with enhanced biological phosphate removal showed no uptake of acetate or release of phosphate under anaerobic conditions. Researchers have also identified that the mesophilic, anaerobic, gram-negative bacteria *SB164P1* as the first bacteria to grow by disproportioning of inorganic sulfur compounds (Riffat et al., 1999).

2.3.2 Sulfate Reducing and Methanation Bacteria

Sulfate containing wastewater under anaerobic conditions showed that both propionate and H2/CO2 were completely utilized by sulfate reducing bacteria, while methanogens outcompeted the sulfate-reducers for acetate. A consortium of methanogenic and sulfate reducing bacteria were found responsible for net oxidation of methane under anoxic conditions. Large sulfate loadings have been found to reduce the microbial activity in terms of methane production and sulfate reduction rates (Riffat et al., 1999).

2.4 Influence of Operational Parameters on Reactor Performance

Operational parameters have major effects on the overall reactor performance. The main operation conditions, which are monitored, are pH, temperature, and hydraulic retention time (HRT) (Guerrero et al., 1999). These three factors affect solid separation, bacterial action, and biogas production. The effect of some of these parameters is covered in detail below.

2.4.1 Hydraulic Retention Time (HRT)

A study on Anaerobic Sequencing Batch Reactor (ASBR) treating synthetic non-fat dry milk at different HRTs (48, 24, and 12 hours) indicated that the COD removal was particularly good at the COD loads of 2 to 8 g/L.d, and reduced slightly at the COD loads of 10 and 12 g/L.d at an HRT of 12 hours. On the other hand, the granulation process and increase in particle size were affected positively by reducing the HRTs from 48 to 24 and then to 12 hours (Sung and Dague, 1995).

The effect of HRT on the Total Organic Carbon (TOC) removal and nitrobenzene conversion to aniline was observed under aerobic treatment conditions. The results indicated that TOC removal in the acidogenesis stage increased by increasing the HRT. The effect of increased HRT on nitrobenzene conversion was obvious at nitrobenzene concentrations higher than 102 mg/L, and the conversion rate remained unchanged at lower concentrations (Ng et al., 1999).

2.4.2 Hydraulic Loading Rate (HLR)

Hydraulic loading rate has to be established for each reactor in order to avoid total reactor failure. Experiments on down-flow stationary fixed film reactors (DSFF) treating bean blanching waste indicated that when HLR increased threefold to (30 kg COD/ m^3/day), the total reactor failure was evidenced by a complete loss of COD conversion efficiency, a sharp raise in volatile fatty acids (VFA), a decrease in pH (to pH 5.4), and sharp drop in methane production rate (Duff and Kennedy, 1982). They concluded that thermophilic DSFF reactor is less stable under overloading conditions than of mesophilic reactor.

2.4.3 Organic Loading Rate (OLR)

Studies on the effect of organic loading rate (OLR) on the efficiency of the COD removal in Fluidized Bed Reactor (FBR) and Anaerobic Filter (AF) were performed by a number of researchers. The results indicated that stationary packed bed, with a corrugated plastic support, operated under stable conditions at organic loading rates around 20 kg COD $m^{-3}d^{-1}$ gives maximal total COD removal of 76% at OLR of 6.29 kg COD $m^{-3}d^{-1}$. The anaerobic filter, with an open pore sintered glass support gives a total COD removal of 84% with an OLR around 12.5 kg COD $m^{-3}d^{-1}$. The fluidized bed reactor, operated on open pore sintered glass media, gives a total COD removal of 96% at an OLR of 5.88 kg COD $m^{-3}d^{-1}$ (Perez et al., 1998).

Duff and Van Den Berg (1982) experimented on the effect of effluent concentration on OLR in a down-flow stationary fixed film reactor (DSFF) treating a high protein fish processing waste. They concluded that once an active biofilm was developed in the reactor, a high steady state loading rate could be maintained at short HRT, without affecting the reactor stability. At OLR of 10 kg COD/ m^3/day or higher, the COD removal efficiencies up to 90% were achieved. When the reactors were fed with a more dilute waste (6 kg COD/ m^3), similar OLR (10 kg COD/ m^3/day) values were achieved, but affected negatively the COD conversion efficiency, and as a result, the volumetric methane production decreased.

Duff and Kennedy (1982) experimented on the effect of organic overloading on DSFF using bean-blanching waste as substrate. They found that DSFF reactors were able to recover from loading rates of 20-30 kg COD/ m^3/day for a 24-hour period, but failed to recover when the OLR was increased to 35 kg COD/ m^3/day. At this OLR concentration, the COD removal efficiency was lost, VFA levels increased, pH dropped to 5, and methane production rate decreased sharply. Furthermore, they concluded that thermophilic DSFF reactor is slightly more stable under organic than hydraulic overloading conditions, possibly due to the increase in alkalinity associated with higher feed strength.

The removal efficiencies of two Anaerobic Filter (AF) laboratory reactors under different OLRs were studied. One treating soybean waste (LSB) packed with a soft fibrous media and maintained at 35°C in a wooden box, and the second treating municipal wastewater (LMW) filled with cylindrical plastic rings with a specific surface area of 220 m^2/m^3 and maintained at an average temperature of 24° C. The removal efficiencies of both LMW and LSB anaerobic filters changed with the OLR under all operational phases. The general trend was that the greater the OLR, the lower the COD removal. This indicates that the OLR controlled the anaerobic filter's performance (Wilson et al., 1998).

2.4.4 Temperature

Anaerobic systems are classified based on the temperature they operate on into two categories: 1) mesophilic, with a reactor temperature around 31°C +/-2 (Sivanthu and Kasturi Bai, 1998; Tay and Zhang, 2000); and 2) thermophilic, with microorganism multiplying at a temperature greater than 55-60 °C. Wastewater treatment specialists define thermophilic treatment as a treatment process taking place at a temperature of 45 °C or higher (Lapara and Alleman, 1999).

There is always an optimum temperature range for a particular waste in anaerobic digestion system. Experiments on anaerobic treatment of industrial wastewater containing organic solvents indicated that once a suitable bacterial population is established, anaerobic digestion proceeds equally well at temperature ranges between 25 to 40 °C inclusively, provided that the population is maintained at the temperature to which it was adjusted. An optimum temperature for the anaerobic digestion of iso-propanol was determined at 35° C as at this temperature the higher value of the maximum specific growth was determined (Terzis, 1994).

The temperature effect was studied on the degradation of 2,4,6-trichlorophenol using anaerobic-aerobic treatment, operating in batch and continuous mode, based on Michaelis-Menten kinetics. It was found that when temperature was maintained at 19° C, it took 70 hours for the degradation process to start. The dehalogination process increased significantly when temperature of the reactor was raised to 30° C (Armenante et al., 1999).

High temperatures may have detrimental effects that are disruptive to the treatment process. For instance, it reduces the surface tension of water, leading to foaming nuisance and process instability. But at thermophilic temperatures, foaming may also indicate high cell concentrations (Lapara and Alleman, 1999).

The thermophilic reactor is usually less stable than mesophilic reactor due to higher susceptibility to temperature change and recovery from feed interruptions or shock loading. Higher temperatures in a thermophilic reactor lead to more fractions of free ammonia, which may have a toxic effect on the methanogenic bacteria (Guerrero et al., 1999). Raising the temperature of a full-scale reactor to 45°C or higher can be a challenge, especially during cold seasons. To save the cost of preheating, the following conditions can achieve free heating: (1) high strength wastewaters suitable for autothermal operation, (2) high temperature wastewaters, (3) locating the reactor under direct sunlight or where an excess heat is available, (4) burning of the methane produced from anaerobic digestion for heating the influent water. The minimum amount of COD removal for autothermal thermophilic operation is around 20,000-

25,000 mg/l. Treating a waste with COD above 30,000-40,000 mg/l. combined with aeration systems with high oxygen transfer efficiency may lead to steady state temperatures exceeding 65-70 ^{0}C. Since these high temperatures are approaching the maximum tolerable for thermophilic bacilli, efforts must be made to avoid such extreme temperatures (Lapara and Alleman, 1999). Recently, Ahn and Forster (2002) concluded that treatment of wastewater from paper mills using anaerobic digestion in the thermophilic range has distinct advantages over the same process in the mesophilic range. But, they recommend further economic study to be done before a firm recommendation can be made. At the same time, Yu et al. (2002) presented similar study on two anaerobic acedogenic reactors, one mesophilic (37 ^{0}C), and one thermophilic (55 ^{0}C) using synthetic wastewater with different organic loading consisting of carbohydrates, fates and proteins. The degree of acidogenesis is decreased by increasing OLR, while no difference was noticed between the two reactors for the COD reduction, and the degree of acidification at any given OLR. However, the thermophilic reactor had a higher substrate degradation rate, biogas production rate, and specific VFA/alcohol production rate than mesophilic reactor.

2.4.5 pH

The pH of the reactor is one of the major parameters affecting anaerobic treatment. The effect of the pH on degradation of 2,4,6-trichlorophenol using anaerobic-aerobic treatment, operating in batch and continuous mode, based on Michaelis-Menten kinetics was studied. The results indicated that when pH of the aerobic process was maintained at 6.5, 7.8, and 9.5 no degradation took place. Degradation of 2,4,6-trichlorophenol was observed when the pH of the reactor maintained in the range of 7 to 7.5 (Armenante et al., 1999). In methanogenesis phase of the anaerobic treatment, at high reactor pH (8), a short solid retention time, and at the presence of substantial population of sulfate reducing bacteria (SRB), the time required for acetate utilizing SRB to out compete the methanation bacteria (MB) is reduced (Riffat et al., 1999).

2.4.6 Toxicity and Inhibition

Studies on continuous anaerobic digesters treating cattle slurry and fish offal indicated that long chain fatty acids cause a digester failure. Six percent fish offal can cause a significant disruption of digester performance. Sulfide concentration of 100 mg/l inhibited reaction in continuous-flow fixed film reactor, and reaction was improved by stripping sulfur from the system. Using a specific toxicity, a toxicity hierarchy of Zn: Cr: Cu: Cd: Ni: Pb in anerobic digestion processes was produced. The effect of sulfide addition on Cu inhibition in methanogenic reactors using acetic acid as an electron donor and electron source revealed that the addition of sulfide before exposure to Cu reduces recovery time (Codina et al., 1998). Experimenting the effect of 4 classes of organosulfur on anaerobic digestion indicated that 5 mmol/L of thiophenes and thiols inhibited methanogenesis (Londry and Soflita, 1998).

Nitro-compounds, such as 3-nitropropionate and nitrate, reduces the production of methane by ruminal bacteria. Heavy metals, such as Cu, Ni, Zn, and Pb, were found to reduce COD removal in UASB reactors. Pb had the greatest effect on acidogenesis and methanogenesis. Testing the toxicity of formaldehyde to anaerobic degradation of glucose in batch reactors revealed that 300 mg/L of formaldehyde caused a 50% inhibition (Riffat et al., 1999).

The experiment on degradation of 2,4,6-trichlorophenol using anaerobic-aerobic treatment, operating in batch and continuous mode, based on Michaelis-Menten kinetics, indicated that at low 2,4,6-trichlorophenol concentrations of 40-15 M no dehalogination inhibition or toxicity effects were observed. Total inhibition occurred when the concentration was raised to 908 M (Armenante et al., 1999).

2.4.7 Addition of Anti-Inhibition Material

Ammonia inhibition of anaerobic thermophilic CSTR treating swine manure, taking into account the sulfide inhibition effect was experimented by Kaare et al. (1999). Different methods for improving biogas yield were examined, such as addition of activated carbon (AC), glauconite, and bentonite bound oil (BBO), and sedimentation of the biomass and particles within the reactor. In the batch experiment the addition of AC 2.5% (w/w) or higher reduced inhibition. Addition of 0.5-1.0% (w/w) doubled the methane yield, but reached 10% of B0 after 68 days. AC did not adsorb ammonia, since no significant change in pH and ammonia was observed at the end of the experiment. Addition of 23 gS2-/l or higher sulfide resulted in inhibition, and the methane production decreased from 165 ml/g-VS with 10 gS2-/l to 100 and 62 ml/g-VS with 23-36 gS2-/l. Sulfide inhibition could be counter acted by the addition of AC or Fe^{2+}, and adding a combination of AC and Fe^{2+} did not further increase biogas production.

In the CSTR experiment, increasing the HRT increased the methane yield from 102 to 182 ml CH4/g-VS. Addition of 1.5% (w/w) AC or 10% (w/w) glauconite increased the steady state methane yield by 88% or 34%, respectively, compared to that of the thermophilic control. Supplying the AC reactor after 72 days with glauconite increased the steady state methane yield 191% compared to the thermophilic control.

Several methods for increasing the methane yield of inhibited reactors are: increasing the HRT, sedimentation of the biomass/particles within the CSTR, addition of AC, glauconite, or methanogenic granules. The above experiment could confirm the previous findings that inhibition by ammonia is counteracted with addition of BBO. Addition of AC leads to: 1) removal of most of the soluble sulfide form 36 mg-S/l to <2mg-S/l; 2) decrease in acclimation time of the anaerobic process; and 3) creation of an immobilized matrix for bacteria (Kaare et al., 1999).

The degradation of phenol, with and without glucose as a co-substrate, using batch and continuous reaction using anaerobic sludge blanket (UASB) was experimented. The substrate was an aqueous solution of 50,000 mg/l phenol, prepared from pure crystal phenol. At phenol concentration of 420 mg/l, the addition of 500-2,000 mg/l of glucose enhanced the degradation rate. On the other hand, 4,000-8,000 mg/l glucose supplies delayed phenol degradation, due to overloading the bacteria with food. At phenol concentration of 840 mg/l and 500-2,000 mg/l glucose supplement, the phenol removal rate was higher (Tay et al., 2001). Butyric acid (Hbu) is better digested by methanogens during anaerobic digestion in the presence of heavy metals, such as Mn, Zn, Ni, Fe, and Cu (Riffat et al., 1999).

2.4.8 Food Microorganism Ratio (F:M)

Studies on factors affecting solid separation and performance of Anaerobic Sequencing Batch Reactor (ASBR) indicated that food: microorganism ratio (F:M) affects bio-flocculation in a way that at low F:M ratios, the biomass flocculated well and settled rapidly, making the reactor effluent low in SS. Lower F:M ratio can be achieved by two ways: lowering the food concentration or increasing the mass of microorganisms (Sung and Dague, 1995).

2.4.9 Effluent Recycle

In general, recycling the effluent in anaerobic treatment systems tends to reduce the removal efficiency, since the reactor approaches complete mix and decreases the mass transfer driving force for substrate. Nevertheless, there are some advantages as well as disadvantages to effluent recycling. The advantages of effluent recycle are: (1) recycling 20% of the effluent lead to 30% increase in the methane yield; (2) reduce the problems associated with low pH caused by high levels of volatile acids; (3) discourages growth of gelatinous bacteria at the reactor inlet; (4) dilution of toxicants and reduction of substrate inhibition (Barber and Stuckey, 1999).

Some disadvantages of the effluent recycle are: (1) encourages solid loss; (2) the amount of dead space doubled to 40% when the recycle radio was increased from zero to 2; (3) increase in sludge volume index has been reported when recycle used with anaerobic filters; (4) benefits associated with the separation of acidogenic and methanogenic phases are lost (Barber and Stuckey 1999a, b).

2.5 Modeling

The most useful tool for designing anaerobic treatment systems and assessing their performance is a mathematical model. Numerous mathematical models for anaerobic filters have been cited by Wilson et al., 1998, such as Performance Curve Fits (Young and Dahab, 1983), Mechanistic Models (Bhadra, 1984, and Lindgren, 1983), Steady-State (Kanaki and Matsu, 1985, and Mosey, 1983), Models and Dynamic Models Incorporating Descriptions of Substrate Diffusion through the Biofilm (Annachhatre and Khanna, 1990; Williamson and McCarty, 1976; and Suidan and Wang, 1985). All these models assume either an ideal continuously stirred tank reactor (CSTR) or ideal plug-flow.

Mathematical modeling is made complicated by several factors, some of which are: (1) the complexity of anaerobic biofilms; (2) the uneven distribution of the film in the reactors; (3) the presence of micro-colonies, and the vent structure; (4) interactions between different microbial species. Since kinetics of the anaerobic digestion are not yet sufficiently developed, Empirical relationships based on experimental results are usually established to predict the relationship between the removal efficiency of the organic matter and other parameters (Wilson et al., 1998).

Wilson et al. (1998) established an empirical model for anaerobic filters using a linear regression analysis of the experimental results and predicted the outlet COD concentrations using inlet COD and hydraulic retention time (HRT). The procedure used two laboratory scale anaerobic filters, one treating domestic wastewater and the other treating soybean processing wastewater, and a pilot plant and a full scale plant of anaerobic filter both treating soybean wastewater.

Arrnenante et al. (1999) carried out mathematical modeling for the degradation process of 2,4,6-trichlorophenol, using anaerobic batch/continuous and aerobic treatment, and determined the kinetic constant. Their whole experiment was based on Michaelis-Menten kinetics. A modified Stover-Kincannon model was successfully used to predict the substrate removal rate. The overall reaction order was proposed to be half order. A general model of immobilized aerobic/anaerobic bacterial system demonstrated that immobilization of bacterial species accelerated the rate of biotransformation and provided complete transformation of toxic intermediates. An experimental study and dynamic model of the effect of biofilm size and mass transfer in a pilot-scale fluidized bed reactor (FBR) indicated that the biomass composition of the biofilm was dependent on the size of the biofilm. Thick biofilms had lower acidogenic activity and higher methanogenic activity compared to thin films (Riffat et al., 1999).

A mathematical model developed by Bello-Mendoza and Sharatt (1998) to describe the dynamic behavior of anaerobic sludge digesters under non-ideal mixing conditions emphasized the importance of mixing conditions in the simulation of anaerobic digestion, reactor design, and calculation of conversion efficiency.

A mathematical model for explaining the complex pattern of volatile acid production in anaerobic digestion process was carried out by Mosey (1983). Hydrogen-utilizing methane bacteria were identified as the controlling organisms for the redox potential of the anaerobic digestion under normal operation conditions. The study proposed that the various mixtures of acetic, propionic, and butyric acids that appear in anaerobic digesters when operating under stress are the response of acid-forming bacteria to change the redox potential of their growth media brought about by changes in the trace concentrations of hydrogen in the digester gas (Mosey, 1983).

A dynamic model for a two-step anaerobic process was developed and tested in batch cultures with two types of organic loads; pea bleaching wastewaters and a synthetic substrate containing sucrose and organic acid. The model allowed simulating satisfactorily the methane production under very different operational conditions (Moletta et al., 1986).

A mathematical model developed by Thomas and Nordstedt (1993) represented a wide variety of anaerobic reactor types and substrates. The model, a generic anaerobic digestion model, using lumped substrate parameters, developed for use as type-specific reactor model operating within the sphere of a larger system model. Three types of anaerobic reactors were simulated: fixed-bed reactors, conventional stirred tank reactors, and continuously expanding reactors. The generic anaerobic digestion model performed very well as a tool for testing various values of conversion efficiency and kinetic parameters for a wide range of substrate types and reactor designs. The model was able to simulate literature data from 44 studies of the three types of reactors, using several different substrates within the 95% confidence interval.

Both the model's strength and weakness lie in its simplicity. The use of lumped parameters and only two bacterial population limits the accuracy of the model. However, the model is adequate enough as a toll for use in the initial design of a reactor system. Even though pilot studies and more detailed modeling may be required in the final design process (Thomas and Nordstedt, 1993).

2.6 Applications of Anaerobic Treatment Systems

A feasibility study on raw and pre-clarified potato-maize wastewater in a UASB reactor achieved 63% COD removal at an organic load of 14 g COD/L.d. Comparative studies on treating distillery wastewater under thermophilic conditions revealed that anaerobic fluidized bed reactor (AFBR) was more effective than anaerobic filter (AF). AF is suitable for easily biodegradable wastewater, while AFBR is more suitable for hazardous waste treatment (Riffat et al., 1999).

Steed et al. (1998) reported that an up-flow packed anaerobic filter operating with SBR for treatment of metal contaminated liquid was able to achieve 99% metal removal at ph 7.2 and produced an effluent closing to drinking water. ASBR treating nonfat dry milk supplemented with nutrients and trace metals showed unique characteristics of removing organics from dilute wastewater at low temperatures ranging from 5-25°C. A two-phase acidogenic and methanogenic digester was used for treatment of dairy wastewater at laboratory scale. The COD removal rate of 90% was achieved for a loading rate of 5 kg/COD/m^3.day.

A one-stage CSTR was found inefficient in anaerobic treatment of propionate derived from carbohydrate wastewater. A two-stage CSTR is needed since contact time and F:M ratio are critical parameters. Sulfide-rich anaerobic sludge and molasses

wastewater were used for reduction of nitrates and nitrites in CSTRs. The result indicated that a COD/N-Nox ratio greater than 65.6 did not convert nitrogen oxide to ammonia. An anaerobic mesophilic filter was able to treat brewery wastewater with 8 kg/COD/m^3.d loading up to 96% COD removal at ambient temperatures.
Treatment of swine waste by anaerobic digestion followed by aeration and sedimentation can produce an effluent that meet the criteria for irrigation and produced no odor (Riffat et al., 1999).

Upflow anaerobic hybrid blanket (UAHB) reactor has been successfully used in treating wastewater containing high sulfate and ammonia concentrations by adding water adsorbing polymer (WAP) particles to the inoculum. Some researchers used ozonation as a pretreatment to anaerobic digestion in treating olive oil mill effluent. Others reported that ozonation produces oleic acid that is more toxic to methanogens than the original substrate.

Tay and Zhang (2000) studied the effect of various shocks on the stability of three types of high-rate anaerobic reactors, using laboratory scale reactors, under mesophilic temperatures (35°C +/- 1). The three types of reactors are: anaerobic fluidized bed reactor (AFBR), anaerobic filter (AF), and upflow anaerobic sludge blanket reactor (UASB). Table 2.3 displays the three reactor performances under normal operation state. The stability of the three reactors in the presence of various shocks was ranked as follows: -

1. UASB ≈ AFBR > AF for twofold organic loading rate (OLR).
2. UASB ≈ AFBR > AF for twofold OLR and twofold HLR.
3. UASB > AFBR > AF for fourfold HLR.
4. UASB > AFBR > AF for fourfold OLR.
5. AFBR > UASB > AF for bicarbonate absence.
6. AFBR > AF > UASB under toxic conditions.
7. UASB ≈ AFBR ≈ AF for under-load (no OLR).

In a second study, the stability of three high rate anaerobic reactors (AFBR, AF, and UASB), in the presence of various shocks was investigated by examining the variance of fuzzy stability index (*N*). The Substrate was soluble and highly biodegradable synthetic wastewater (mainly glucose, peptone, and meat extract) containing essential

Table 2.3 Performances of AFBR, AF, and UASB under normal operation conditions (Tay and Zhang, 2000).

Reactors	Gas Production (L/h)	H_2 (ppm)	CO_2 (%)	CH_4 (%)	pH	Effluent TOC (mg/l)	Effluent VFA (mg/l)
AFBR	0.57-0.86 (0.663)	49-299 (158)	12.34-24.69 (18.99)	67.24-75.04 (7.26)	7.12-7.37 (7.26)	28-196 (63.94)	1.80-149.2 (50.46)
AF	0.49-0.63 (0.561)	185-556 (290)	21.78-30.15 (25.04)	65.94-70.73 (68.11)	7.05-7.39 (7.26)	65-254 (122.4)	28.5-287.0 (112.5)
UASB	0.72-0.87 (0.780)	110-391 (203)	17.06-29.8 (25.45)	65.26-71.66 (68.72)	6.98-7.27 (7.21)	32-87.6 (48.67)	35.7-54.82 (45.25)

macro- and micro- nutrients for bacterial growth, stored at 4°C to avoid premature degradation. The reactor was operating under mesophilic temperatures, and the parameters such as HRT, OLR, COD, and $NaHCO_3$ intentionally varied during 7 cycle tests to assess performance. Fuzzy stability index (*N*) variance explicitly indicated the departure of a system from normal state. The curve of *N* versus time clearly indicated the shifting rate and recovery time of a system, whereas a direct examination of the system performance could not offer such evident information (Tay and Zhang, 2000).

Chapter 3

Process Description and Industrial Waste Survey

3.1 Introduction

This chapter focuses on the anaerobic/aerobic treatment of industrial wastewater produced by Seville Products Limited. This company is located at Al Quoz Industrial Area in Dubai and produces different kinds of chocolate confectionery products, biscuits, and pasta. The wastewater is generated as a result of the washing process of moulds, utensils, and mixing vessels. Moulds are washed automatically in a way similar to a dishwasher, while the bigger parts are washed manually. The wastewater is discharged intermittently, 1 to 4 batches per day, at a total volume of 50-150 m^3/day. The effluent is high strength wastewater containing a complicated mixture of emulsified oil, suspended solids, and sugar.

Since Dubai Municipality (DM) has a stringent law for the quality of the waste being discharged to any environment or sewer line, the effluent must be treated to achieve the DM sewer discharge standard. The treatment system under study is set-up and has operated by Rentec Environment Protection Technology in Dubai. Description of wastewater treatment plant and its industrial waste survey will be presented in this chapter.

3.2 Process Description

The treatment process, utilized for Seville Products Ltd., is a two-phase (Acetogenesis / Methanogenesis) process followed by aerobic polishing stage as demonstrated in Appendix 4. The plant is automatically controlled and the instruments consist of automatic control, manual control, protective system, trip system, and alarm system.

A full description of the treatment stages is given below. Wastewater produced from food industries is high in organic contents, such as lipids and more easily degradable compounds, such as carbohydrates and proteins. The organic suspended solid content of the wastewater does not encourage the use of high rate anaerobic reactors, such as anaerobic filters and up-flow anaerobic sludge beds (UASB). A two-phase anaerobic system is the most suitable for this type of wastewater as discussed in Chapter 2 (for instance, Guerrero et al., 1999).

3.2.1 Influent Lift Station and Mechanical Cleaning

Influent lift station is equipped with 2 submersible pumps, one in duty and one standby, with a capacity of 25 m^3/h each working on float switches to ensure optimum operation conditions. The effluent received from the last manhole is pumped at this station for mechanical cleaning. The mechanical cleaning is carried out by flowing the influent through a rotating drum screen, with a mesh size of 0.5 mm, and a capacity of 25 m^3/h. At this stage floating particles are removed and the relatively solid free wastewater flows via gravity to the inlet lift station.

3.2.2 Inlet Lift Station

The inlet lift station is also equipped with 2 submersible pumps, one in duty and one standby, with a capacity of 25 m^3/h each operated by float switch. This lift station is designed to receive in addition to wastewater from mechanical cleaning the supernatant coming from the sludge tank as well as recycled water in case of emergencies or off-spec cases. The influent here is pumped into the equalization tank (acidogenesis reactor).

3.2.3 Acidogenesis Reactor

Acidogenesis reactor is the first phase of anaerobic process and is also known as hydrolysis - acidification phase. It has the following main functions:

1. Balancing the effluent when experiencing fluctuations in the flow rate.
2. Converting sugar and organic suspended solids to volatile fatty acids (VFA), such as acetic, propionic, and butyric acids.
3. Providing continuous flow rate for the methanogenesis reactor.

The tank volume is 308 m^3, in which the influent can be accommodated for 2 days during maximum peak-flow conditions. The reactor is equipped with level control and pH adjustment systems. The pH adjustment system consists of chemical tank (NaOH), dosing pumps, and single input pH controller which sends information via a 4-20 mA signal to the chemical dosing pump controlling the flow of the chemical to the tank. Additionally, the reactor is equipped with a re-circulation system to main the content moving for achieving better fermentation and conditioning. When hydrolysis – acidification is completed, the effluent is pumped into the methanogenesis reactor via dry installed pumps (re-circulation and feed) connected directly at the side of the reactor tank.

3.2.4 Methanogenesis Reactor

Methanogenesis, also known as acetogenesis-methanation, is the phase where the VFA is converted to methane gas. This reactor can be operated under either thermophilic (45° C+) or mesophilic (31° C +/-2) conditions. In our case, the reactor is operating under mesophilic conditions depending only on natural climate and the heat of the influent wastewater. The reactor is equipped with re-circulation device, bacteria retaining media, level control, and pH control. The average biogas production is about 200-600 m^3/day. The ratio of pure methane amount is around 50%. The recovered gas is flared into atmosphere.

3.2.5 Solid / Liquid Separator

The flow coming from the methanogenesis reactor will enter the lamella separator to separate anaerobic digested sludge from the liquid. The sludge is removed from the bottom of the separator to the sludge tank, while the liquid flows into the aerobic treatment tank.

3.2.6 Aerobic Treatment

This is an activated sludge process consisting of an aeration tank equipped with 2 air blowers with a capacity of 1,200 Nm^3/each, providing the required amount of dissolved oxygen (2 mg/l/min.). The biological oxidation of the organic load is achieved by transferring the required oxygen into the biomass. The aeration takes place through non-cloggable fine bubble diffusers, located and distributed at the bottom of the tank. The fine bubble diffusers further provide constant mixing velocity and homogeneous oxygen transfer through the mixture. The sludge particles will remain suspended in the aeration tank throughout the aeration period.

Bacteria and mono-cell organisms degrade the organic and ammonium content of the wastewater, converting them to CO_2 and nitrates. According to the wastewater flow into the aeration tank, a constant amount of activated sludge is transferred from the aeration tank into the sedimentation tank. There the biomass is separated from the treated water. Part of the sludge is pumped back into the aeration tank to activate additionally the biological process, while the rest is transferred into the sludge holding tank.

3.2.7 Sludge Thickening and De-watering

The sludge holding tank is equipped with aeration system to maintain the content under aerobic conditions. During sludge thickening, the supernatant liquor flows via gravity through an overflow system into the inlet lift station for further treatment, while the thickened sludge, containing 1.5-2.0 % dry solids, is pumped into the sludge de-watering unit.

Dubai Municipality environmental regulations mandate that the disposed sludge must contain a minimum of 25% dry solids by volume. For this purpose the sludge is further de-watered mechanically to reach the specified standard. The sludge de-watering system is a packed unit consisting of sludge feed pumps, flocculent dosing system, belt filter press, and control panel. The sludge cake after belt pressing is collected in a container for landfill disposal, while the filtrate is recycled through the Inlet Lift Station for further treatment.

3.2.8 Final Effluent Control

The completely treated water flows into final effluent control tank. There, the pH is further adjusted automatically, if required, before diverting to sewer line or using for wash processes.

3.2.9 Air Purification and Biogas Flaring

Anaerobic units producing waste air are connected to the air-cleaning unit. The air-cleaning unit is connected to a bio-filter media, where microorganisms carry out biochemical oxidization of certain organic and inorganic gaseous compounds. Unwanted constituents of the treated gases serve as a substratum for the microorganism and are converted into comparatively non-problematic by-products (H_2O, CO_2, biomass, salts, etc.).

The biogas is stored at the top of the methane reactor where it is connected with a high/low pressure control system and the gas burner. The flare is automatically operated, in such a way that when the gas pressure inside the reactor rises to the limited value, the control valve opens and ignition system switches on. When the pressure inside the reactor drops to a certain value, the control valve is automatically closed and the ignition system switched off.

3.3 Process Design Parameters

3.3.1 Wastewater Characteristics

Daily Discharge Output	:	150 m^3/d
Average Hourly Flow	:	6.25 m^3/h
Peak Hourly Flow	:	25 m^3/h
BOD_5	:	1000-6000 ppm
COD	:	4000-12000 ppm
Oil & Grease	:	500-7500 ppm
TSS	:	600-11000 ppm
TDS	:	1200-8500 ppm
pH	:	5-11
Water Temperature (Max)	:	50 ^{0}C

3.3.2 Acidogenesis Reactor Configuration

Equalization Capacity	:	150 m^3
Hydrolysis Capacity	:	75 m^3
Emergency Capacity	:	75 m^3
Volume Required	:	300 m^3
Actual Volume	:	308 m^3

3.3.3 Methanogenesis Reactor Configuration

3.3.3.1 Basic Data

Daily Discharge Output	:	150 m^3/d
Peak Hourly Flow	:	25 m^3/h
BOD_5	:	6000 ppm
COD	:	12000 ppm
Water Temperature (Max)	:	50 ^{0}C
Sludge Load	:	1.25 kg/kg
Volumetric Load	:	6.0 kg/m^3.d
Sludge Production	:	0.1 kg/kg
Dry Solids in Biology	:	4.0 kg/m^3
Dry Solids in Excess Sludge	:	12 kg/m^3
Volume Required	:	300 m^3
Actual Volume	:	300 m^3

3.3.3.2 Gas Production

Spec. Gas Production	:	0.45 m^3/kg $COD_{oxidized}$
Efficiency	:	70%
COD Oxidized	:	1260 kg COD/d
Average Gas Production	:	567 Nm^3/d

3.3.3.3 Sludge Production

Sludge Production	:	126 kg/d
Daily Digested Sludge Production	:	10.5 Nm^3/d

3.3.4 Activated Sludge Design Configuration

3.3.4.1 Basic Data

Daily Discharge Output	:	150 m^3/d
Peak Hourly Flow	:	25 m^3/h
BOD_5	:	6000 ppm
COD	:	12000 ppm
Water Temperature (Max)	:	50 ^0C
Sludge Load	:	0.2 kg/kg
Volumetric Load	:	0.9 $kg/m^3.d$
Sludge Production	:	0.5 kg/kg
Dry Solids in Biology	:	4.0 kg/m^3
Dry Solids in Excess Sludge	:	7.0 kg/m^3
Volume Required	:	300 m^3
Actual Volume	:	300 m^3

3.3.4.2 Sludge Production

Sludge Production	:	135 kg/d
Daily Digested Sludge Production	:	19.3 Nm^3/d
Sludge Surplus after thickening (1.3% DS)	:	10.4 m^3/d
Sludge Surplus after De-watering (25% DS)	:	0.54 m^3/d

3.4 Industrial Waste Survey

3.4.1 Sampling and Analysis

In order to evaluate the Seville Products Ltd. wastewater treatment plant performance, experimental analysis on waste loads and flow at different stages before and throughout the treatment process were conducted. Grab sampling of wastewater was conducted in different seasons through two years. The locations of the wastewater sampling points are indicated on the schematic diagram in Figure 3.1. The type of analysis conducted is indicated in Table 3.1.

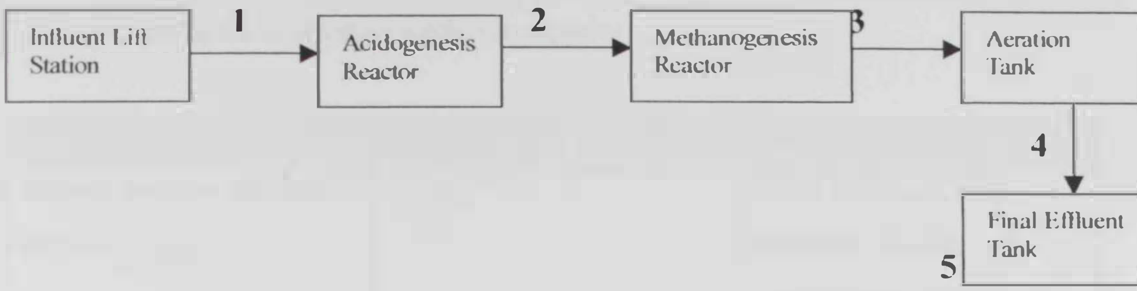


Figure 3.1 Wastewater sampling Points Indicated on Waste Block Flow Diagram

3.4.2 Experimental Materials and Set-up

The following analysis, instruments, and methods indicated in Table 3.1 were used in the UAE University Laboratory in order to evaluate the wastewater quality through out the process. Parallel to these analysis conducted in CLU, and Department of Chemical and Petroleum Engineering, UAE university, final point analysis and sludge analysis routinely were performed in Professional Laboratory in Dubai.

Table 3.1 Analysis Parameters, instruments, and international methods utilized in UAE University CLU to assess wastewater quality

Analysis Parameter	Method	Instrument
Sugars: fructose, glucose, sucrose, …etc.		HPLC (Alliance 2690 separation module with column oven; refractive index detector (2410 vaters); μ bondpack NH2 column 125 AO 10 μm (3.9x300 mm)
Fatty Acids	Liquid-liquid extraction by petroleum ether	Chrompack CP-9001 GC with FID detector, Column: WCOT fused silica 25Mx0.32MM ID, df=0.3 coating FFAP-CB for free fatty acids.
Total Kjeldal Nitrogen (TKN)	ISO 5663	2300 Kjeltec Analyzer Unit, Foss Tecator
Ammonia	APHA 4500-NH#	Spectrophotometric determination (UV-VIS) DR 4000 Hack UV-VIS Spectrophotometer
Oil and Grease	EPA 1664	Gravimetric determination
Heavy Metals		Atomic Absorption

Chapter 4

Results and Discussion

Sampling and preservation time will be presented and discussed in the first section of this Chapter. The results of analysis, that has been conducted in CLU or in certified private lab in Dubai, for influent and effluent of each unit will be discussed and compared with the results of those studies presented in the literature review covered in Chapter 2. Furthermore, the treatment efficiency for anaerobic/aerobic process will be analyzed under different seasonal temperature conditions and compared with the results from an SBR treatment plant that treats industrial wastewater for a company named California Garden in Dubai. Finally, sludge characteristics for the two plants will be presented and discussed. Treated effluent water and sludge produced will be evaluated to find out if their characteristics comply with the Dubai Municipality legislation standards.

4.1 Sampling, Preservation, and Analysis

Throughout the two years of study, grab samples of wastewater were collected at different seasons and at four sampling locations influent and after each treatment stage. The sampling points are as follows: -

Sampling Point	Location
1	Inlet to influent left station
2	Outlet of acidogenesis reactor
3	Outlet of methanogenesis reactor
4	Final treated water

Other analyses results obtained from Seville Products Factory, which was conducting its own sampling and analyzing in a private laboratory, certified by Dubai Municipality. The results of our analysis would have been more indicative if complex samples were collected and analyzed every 2 hours/day. Due to high analysis costs, time consumption, and the transportation constraints only one sample was taken each time. Samples were collected in glass brown bottles, chilled with ice, and taken to University's Central Laboratory Unit (CLU) for analysis. Since the private lab analyzed main organic load parameters, such as BOD_5, COD, TSS, and TDS, we analyzed other indicative parameters, such as volatile fatty acids (VFAs), total fat, oil and grease, TKN, heavy metals and ammonia. The analyses that were conducted in CLU have been replicated twice for each sample as shown, for instance, in Table 4.1. The reproducibility of the data is highly accurate.

The results of analyses conducted in the CLU lab are demonstrated in Tables 1 and 2 and Figure 4.1 for two samples only and full analyses results are shown in Appendix 1. As for the two samples demonstrated in Tables 1 and 2, the request dates were 22/03/2001 and 18/06/2001 and the dates of completion were 7/6/2001 and 27/6/2001, respectively. It is clearly observed that the preservation time has great effects on the final results in spite of chilling the samples in the CLU Lab. The concentrations of all volatile fatty acids except propionic acid in the sample that was preserved for long time (sample with date of request 22/03/2001) as shown in Table 4.1 are not detected in the influent location (sample point 1), while in other locations the differences in concentrations between the two samples are great, for instance at sample point 2, the concentration of valeric acids dropped from 48 mg/l (sample with a short time of preservation) to 6 mg/l (sample with a long time of preservation) as demonstrated in Tables 4.1 and 4.2 respectively. Figure 4.1 shows the effect of preservation time on valeric acid concentration variation between two samples as an example. These observations may reveal that microorganisms are active even at low temperatures that are recommended for preservation of the samples. For such industrial wastewater from food industries, the preservation time should be shortened as much as possible to avoid misleading results. Figure 4.2 demonstrates the industrial waste survey of the wastewater treatment plant based on the average of the analysis results that conducted in CLU and the private lab.

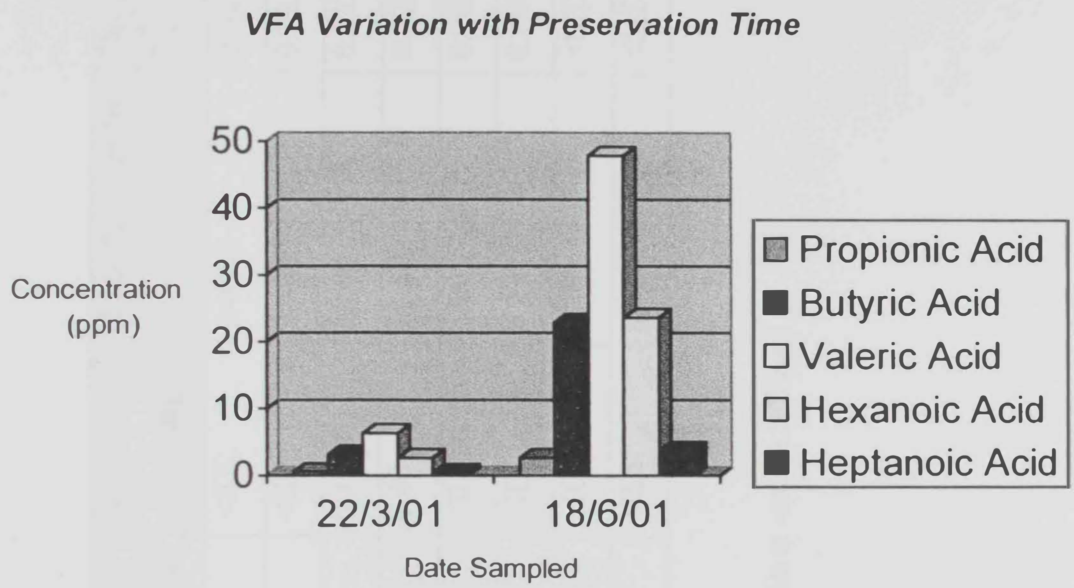


Figure 4.1 Volatile Fatty Acids variation in Acidogenesis Reactor with preservation time

Table 4.1 Analysis results of volatile fatty acids, total fats, protein and sugar (Date of request 22/03/2001 and date of completion 7/6/2001)

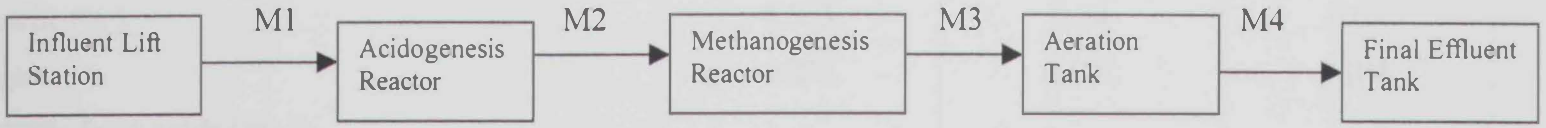
Sample	[2]Propionic Acid (mg/l)	[2]Buteric Acid (mg/l)	[2]Valeric Acid (mg/l)	[2]Hexanoic Acid (mg/l)	[2]Heptanoic Acid (mg/l)	Total fats (mg/l)	[3]% Protein	[1]% Sugars
SP#1 – A	0.090	<IDL	<IDL	<IDL	<IDL	249.60	0.020	<MDL
SP#1 – B	0.093	<IDL	<IDL	<IDL	<IDL	254.00	0.023	<MDL
SP#2 – A	0.540	3.08	6.28	2.60	0.39	89.00	0.012	<MDL
SP#2 – B	0.53	3.12	6.43	2.67	0.40	87.50	0.009	<MDL
SP#3 – A	0.060	<IDL	<IDL	<IDL	<IDL	5.80	0.0008	<MDL
SP#3 – B	0.070	<IDL	<IDL	<IDL	<IDL	6.10	0.00097	<MDL
SP#4 – A	<IDL	<IDL	<IDL	<IDL	<IDL	2.10	<MDL	<MDL
SP#4 – B	<IDL	<IDL	<IDL	<IDL	<IDL	1.90	<MDL	<MDL

1. Method detection limit (MDL) for sugars is 0.2%
2. GC Instrument Detection Limit (IDL) of the applied method for fatty acids in water is 0.07 mg/l
3. Method Detection Limit (MDL) for protein by titrimetry is 0.0006%

Table 4.2 Analysis results of volatile fatty acids, total fats, protein and sugar (Date of request 18/06/2001 and date of completion 27/06/2001)

Sample	[2]Propionic Acid (mg/l)	[2]Buteric Acid (mg/l)	[2]Valeric Acid (mg/l)	[2]Hexanoic Acid (mg/l)	[2]Heptanoic Acid (mg/l)	Total fats (mg/l)	[4]Oil & Grease (mg/l)	[1]% Sugars	[3]TKN (mg/l)	Free NH_3
SP#1 – A	0.200	0.34	0.65	0.31	0.28	348.20	11.60	<MDL	4.03	1.15
SP#1 – B	0.224	0.32	0.69	0.39	0.24	321.90	11.60	<MDL	3.74	1.14
SP#2 – A	2.590	23.18	48.26	23.50	4.01	95.70	6.10	<MDL	7.25	1.05
SP#2 – B	2.62	22.51	47.39	23.80	3.35	116.60	6.10	<MDL	5.80	1.00
SP#3 – A	0.132	<IDL	<IDL	0.129	<IDL	8.00	<MDL	<MDL	107.95	90.60
SP#3 – B	1.120	<IDL	<IDL	0.125	<IDL	7.10	<MDL	<MDL	109.23	91.00
SP#4 – A	<IDL	<IDL	<IDL	<IDL	<IDL	1.60	<MDL	<MDL	2.04	1.05
SP#4 – B	<IDL	<IDL	<IDL	<IDL	<IDL	1.40	<MDL	<MDL	2.23	1.10

1. Method detection limit (MDL) for sugars is 0.2%
2. GC Instrument Detection Limit (IDL) of the applied method for fatty acids in water is 0.07 mg/l
3. Total Kje;dal Nitrogen (TKN) for total nitrogen is carried out by tertiametry
4. Method detection limit (MDL) for Oil & Grease in water is 1.6 mg/l



Parameters	M1	M2	M3	M4
pH	na	na	6.6	8.50
Flow (m^3/d)	60	60	60	60
Inlet Water Temperature ^{O}C	na	na	33.5	na
Total suspended solids (TSS) (mg/l)	588	na	na	249.33
Total Dissolved Solids at 180 ^{O}C (TDS) (mg/l)	4750	na	na	1456.66
Chemical Oxygen Demand (COD) (mg/l)	3500	na	na	512
Biochemical Oxygen Demand (BOD)				
(5 days) at 20 ^{O}C (mg/l)	3500	na	na	249.33
Oil and Grease (Emulsified) (mg/l)	10.60	6.63	‹MDL	‹MDL
TKN (mg/l)	5.56	34.58	98.57	2.59
Free Ammonia (mg/l)	0.60	0.70	117.30	23.04
Phosphate-Phosphorus (PO_4-P) (mg/l)	na	na	na	1.9

Total Fat (mg/l)	317.25	97.42	6.67	1.5
Protein (%)	0.013	0.04	0.03	0.002
Sugar	‹MDL	‹MDL	‹MDL	‹MDL
Volatile fatty acids (mg/l)				
Propionic acid	0.18	2.24	0.12	‹MDL
Butyric acid	0.30	18.13	0.08	‹MDL
Valeric acid	0.59	39.55	0.09	‹MDL
Hexanoic acid	0.38	18.33	0.13	‹MDL
Heptanoic acid	0.25	4.20	‹MDL	‹MDL
Heavy metals (mg/l)				
Aluminum (Al)	160.74	214.86	123.10	7.55
Barium (Ba)	31.95	98.36	20.12	3.97
Cadmium (Cd)	‹MDL	‹MDL	‹MDL	‹MDL
Chromium (Cr)	7.50	8.07	2.20	0.7
Copper (Cu)	24.29	45.04	19.6	2.22
Nickel (Ni)	12.50	17.69	13.0	8.68
Lead (Pb)	2.55	12.3	13.30	0.90
Zinc (Zn)	63.41	157.47	73.02	16.10
Manganese (Mg)	na	na	na	0.08

Figure 4.2 Block flow diagram and industrial waste survey

4.2 Pre-acidification and Equalization Tank

In Chapters 2 and 3, the advantages of using pre-acidification tank, known as hydrolysis-acidification phase, as a first stage for anaerobic process were reported. This reactor tank is further described in Chapter 3. Proteins, for instance, degrade into monomers. Oil, grease and fats are converted by hydrolysis process into volatile fatty acids. This is clearly observed from the results of analysis presented in Figure 4.2 and analysis results attached in Appendix 1. For instance, valeric acid concentration in influent to the tank is 0.67 ppm, while in the tank effluent increases to 48 ppm. On the other hand, the concentration of fats dropped from 348.2 ppm in tank inlet to around 100 ppm in tank outlet. The volatile fatty acids that exist in the effluent stream from the pre-acidification tank are propionic, butyric, valeric, hexanoic and heptanoic acids. The results of Ahn et al. (2001) experiments concluded that an equalization tank could be used simultaneously as a pre-acidification tank, and no need to use separate tank. The same trend is also applied in this plant. The analysis results reveal that the polymers and other organics degraded into volatile fatty acids, but no traces of acetic acids was detected. In this tank the pH is adjusted by adding NaOH solution. The NaOH solution contained heavy metals as demonstrated in the additives analysis results, and this is what is attributed to the increase of heavy metals from influent to effluent streams from this tank.

The fatty acids effluent concentrations from the pre-acidification tank is affected by climate change as depicted in Figure 4.3 and the analysis results shown in Appendix 1. As revealed, the hydrolysis and acidification are highly stimulated by increase in ambient temperature in June, while these two processes decrease by drop in temperature, as indicated in November results. That is clearly demonstrated in Figure 4.3. These findings are in agreement with the results presented in literature (Armenante et al., 1999, Gurerrero et al., 1999). The free ammonia also increased by increasing temperature, for instance free ammonia increased from 0.04 in November to 1.05 ppm in June. This observation also verifies the results presented in the literature (Gurerrero et al., 1999).

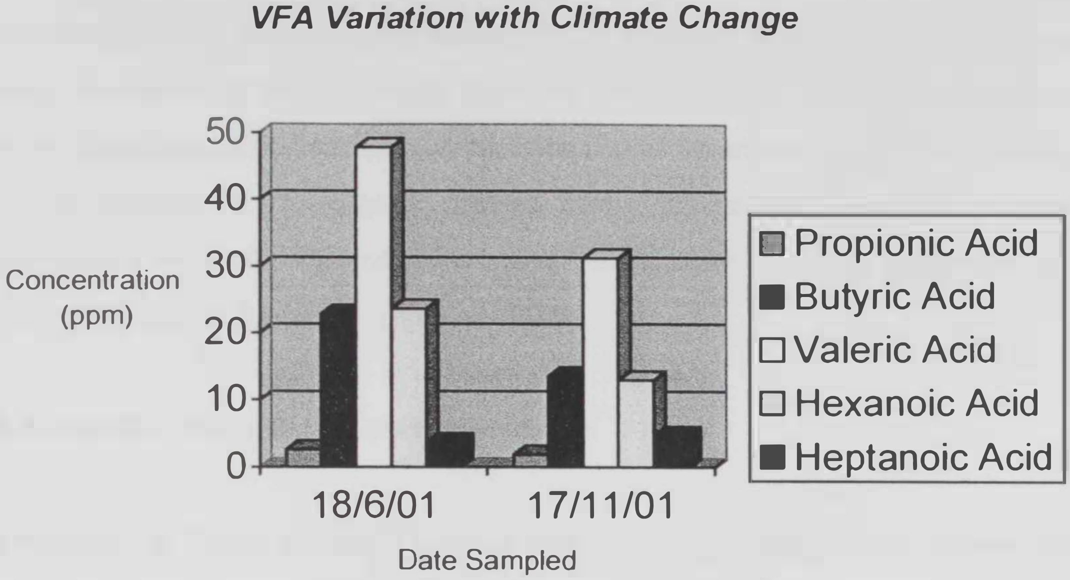


Figure 4.3 Volatile Fatty Acids variation in Acidogenesis Reactor due to climate change

4.3 Methanogenesis Reactor

A methanogenesis reactor is considered as the second stage of anaerobic process and is also known as acetogenesis-methanation where volatile fatty acids are converted to acetic acid and then to methane. This reactor operates under normal climate conditions, controlled pH, and can be operated either thermophilic or mesophilic. As discussed in Chapter 2, mesophilic temperature is around 32 ^{O}C and the optimum is 35 ^{O}C (Terzis, 1994) while thermophilic temperature is greater than 45 ^{O}C. In Chapter 2, we further demonstrated that temperature increase may improve the process performance up to specific temperature depending to the type of wastewater, but at higher temperatures, it can cause reactor instability (Armenante et al., 1999, Lapara and Alleman, 1999, and Guerrero et al., 1999).

Table 4.2 reveals the analysis of organic species from four sampling points reported above. The effluent analysis from methanogenesis reactor depicts that almost all volatile fatty acids and oil and grease are converted to acetic acid and then to methane. But around 5 % of total fats remain without conversion. On the contrary, the TKN and free ammonia increased drastically, for instance TKN increases from 5.8 ppm to 108 ppm. As clearly demonstrated that the results show the performance of this reactor is affected by climate conditions. Aeration unit described as a post treatment unit polishes this process. Most of residue of the organic species from the anaerobic process is treated as demonstrated in Table 4.1 and Figure 4.2. This finding is in full agreement with the results presented by Perez et al. (2001a, 2001b).

4.4 Anaerobic / Aerobic Process Performance

As indicated in Table 4.3 and Figures 4.4 and 4.5, the results for all seasons are well within the Dubai Municipality's effluent discharge limits to sewer (refer to appendix 4). Only TDS for April 2000 analysis is slightly (140 mg/l) above the standards. As it is evident from April, July and August results, we can see that the reactors perform better during hot seasons, especially for BOD_5, COD, and TSS parameters.

Table 4.3: Seasonal effluent water quality 2000 (see appendix1 for full analysis results)

Parameter (mg/l)	**April**	**July**	**August**	**September**	**November**	**DM Sewer Standard**
BOD_5	160	98	220	430	920	1000
COD	524	248	560	728	2560	3000
TSS	34	45	46	296	210	500
TDS	3140	1570	280	2520	1310	3000
O & G	8	22	24	18	28	50

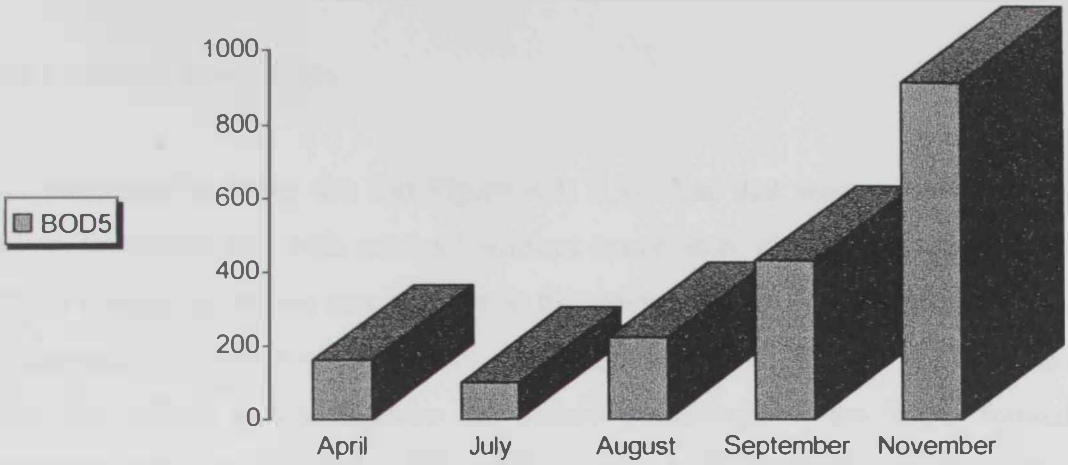


Figure 4.4: Seasonal BOD_5 variation in the effluent treated wastewater due to ambient temperature change

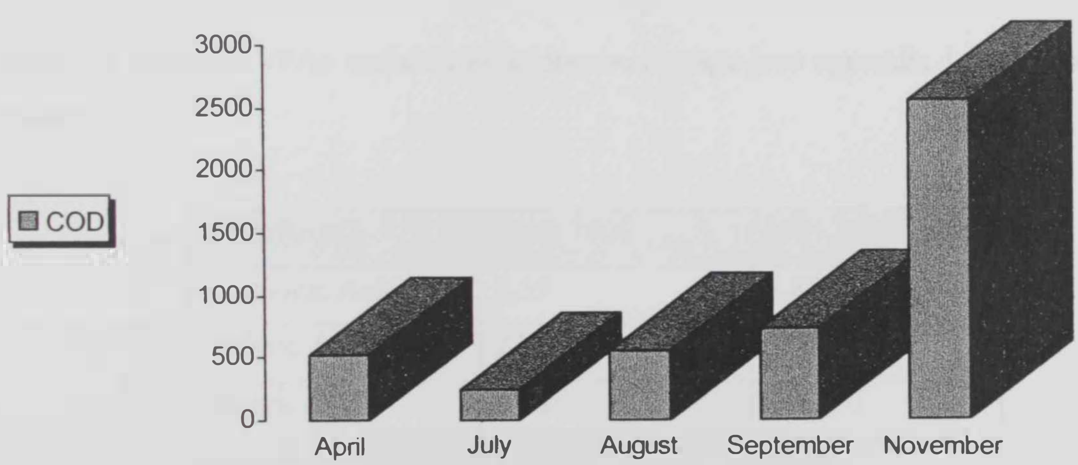


Figure 4.5: Seasonal COD variation in the effluent treated wastewater due to ambient temperature change

4.5 Organic and Heavy Metals Distribution

4.5.1 Volatile Fatty Acids

As illustrated in Table 4.4 and Figure 4.3, it is clear that wastewater degradation and VFAs formation vary with seasonal ambient temperature change. In the hot seasons the VAFs concentrations are much higher in the reactors, which indicate a better break down of organic constituents of the waste. Analyzing the rest of Figures 4.6, 4.7, and 4.8, we find that valeric acid constitutes the highest percentage of the VFAs formed, while propionic acid and heptanoic acid constitute the lowest percentage of the VFAs formed during the conversion. This is especially obvious in the acidogenesis stage of the treatment process.

The listed figures further illustrate that VFAs are formed only in the acidogenesis stage, as their concentration is almost nil in the other three stages of the treatment process. The VFAs are completely converted to biogas in the methanogenesis stage.

Table 4.4 Seasonal VFAs variation in acidogenesis stage (see appendix 1 for full analysis results)

VFA (mg/l)	June 2001	Nov. 2001
Propionic Acid	2.59	1.85
Butyric Acid	23.18	13.71
Valeric Acid	48.26	31.94
Hexanoic Acid	23.50	13.04
Heptanoic Acid	4.01	4.72

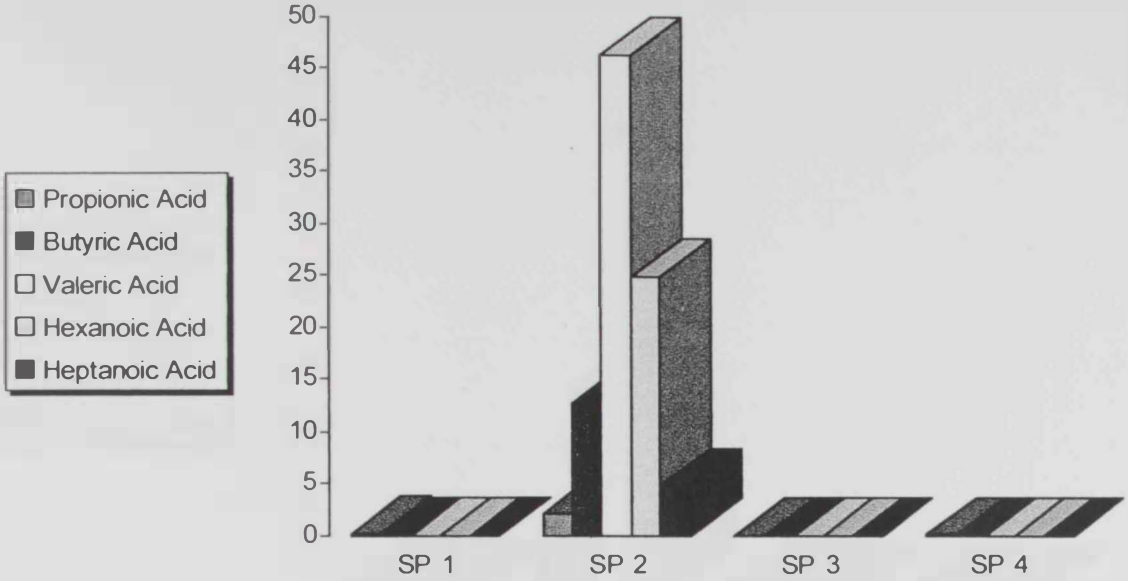


Figure 4.6: VFAs behavior during treatment stages (Sampled: December 2000)

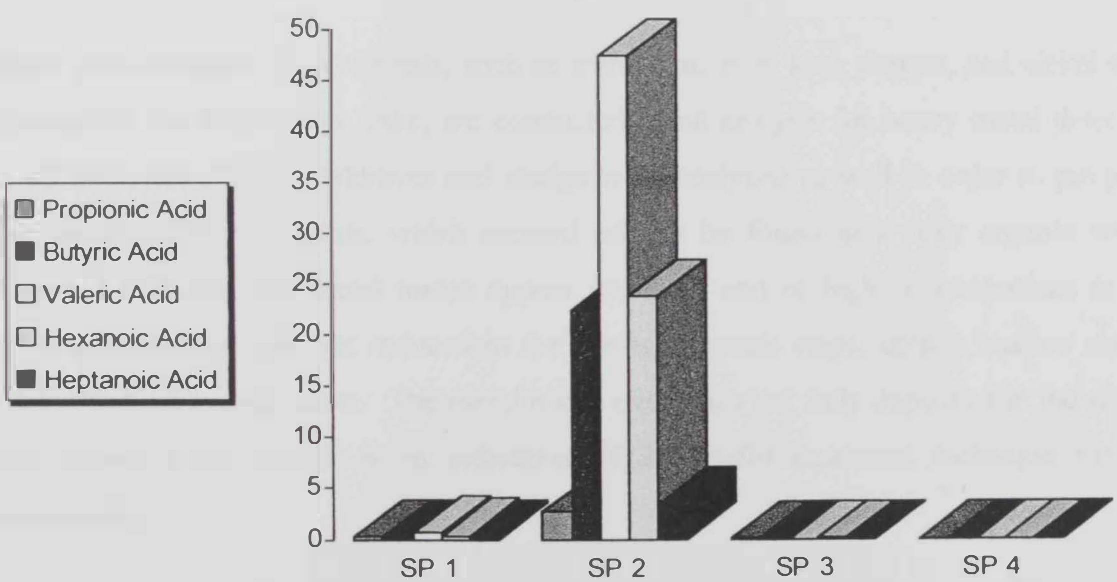


Figure 4.7: VFAs behavior during treatment stages (Sampled: June 2001)

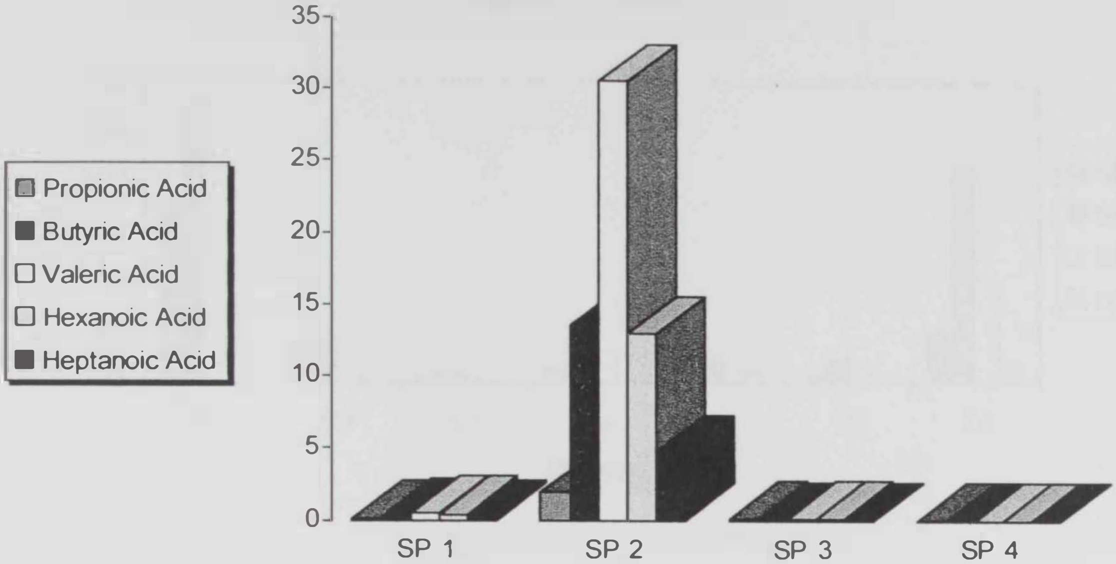


Figure 4.8: VFAs behavior during treatment stages (Sampled: November 2001)

4.5.2 Presence of Heavy Metals

Since some traces of heavy metals, such as aluminum, zinc, lead, copper, and nickel were detected in the final sludge cake, we conducted a full analysis for heavy metal detection at all treatment stages. Additives and sludge were analyzed as well in order to pin point the source of heavy metals, which seemed odd to be found in a fully organic waste. Figure 4.9 shows that metal traces appear suddenly and at high concentrations in the Acidogenesis stage and get reduced in the Methanogenesis stage, until it reaches almost nil in the final treated water. The metal traces eventually get fully deposited in the sludge (see figure 4.10), which is an indication of successful treatment technique for the wastewater.

The source of the heavy metals was found to be the nutrition additive (Urea) and pH controller additive (Sodium Hydroxide). Figure 4.11 indicates the presence of these heavy metals in both additives.

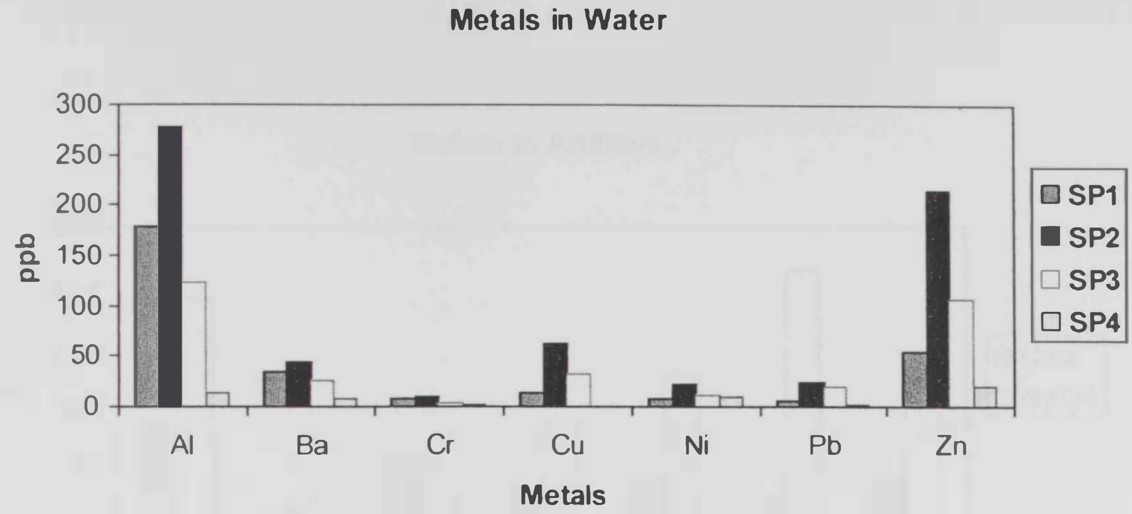


Figure 4.9: Metal traces appeared in wastewater during treatment stages (Sampled: 17/11/2001)

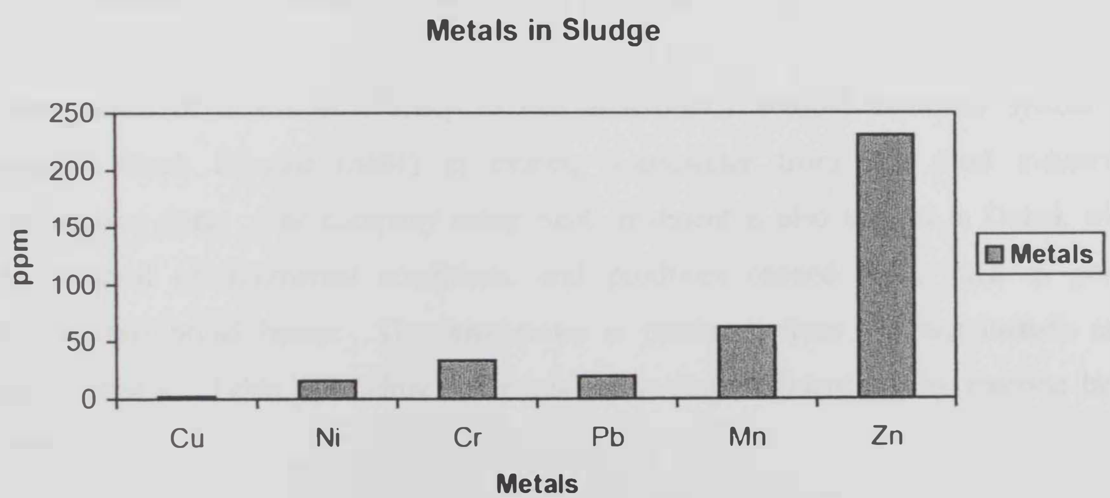


Figure 4.10: Metals accumulated in sludge from ETP (Sampled 9/9/2000)

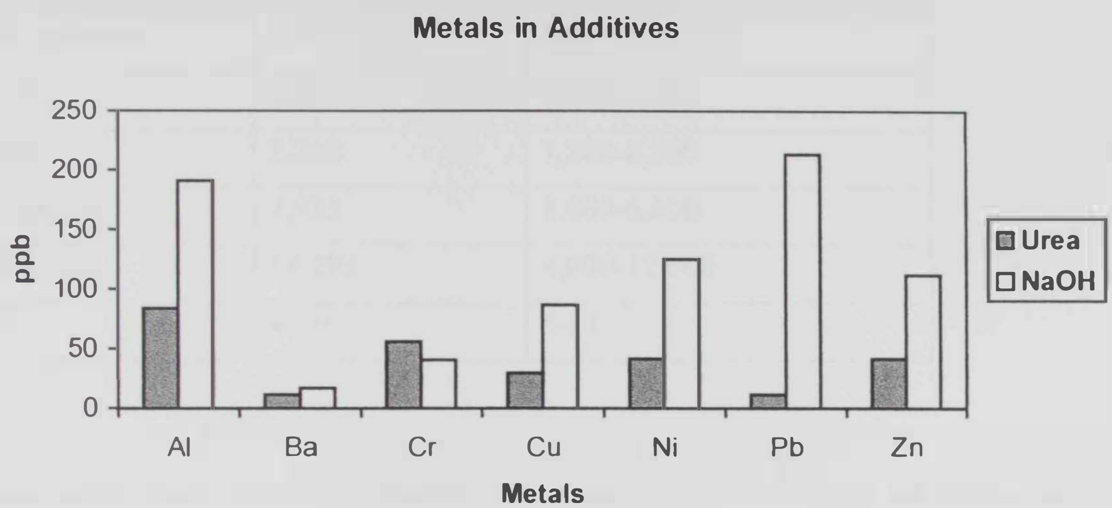


Figure 4.11: Metal traces detected in urea and sodium hydroxide additives (Sampled 17/11/2001)

4.5 A Comparison of Anaerobic / Aerobic Treatment to SBR

A comparison of treatment efficacy of our anaerobic / aerobic treatment system to Sequential Batch Reactor (SBR) in treating wastewater from two food industries operating was done. The company using SBR treatment is also located in Dubai, with same external environmental conditions, and produces canned food, such as peas, chickpeas and broad beans. The wastewater is produced from washing utensils and cooking vessels. Table 4.5 below compares the average influent quality entering both systems.

Table 4.5 Comparison of influent wastewater quality entering SBR to Anaerobic/Aerobic system.

Parameter	SBR (ppm)	Two-Stage System (ppm)
Oil & Grease	150	500–7,500
TSS	300	600-11,000
TDS	2,250	1,200-8,500
BOD	7,933	1,000-6,000
COD	14,293	4,000-12,000
pH	4-10	5-11

Some metal traces were also found in wastewater in the SBR plant, but unlike our two-stage plant, the concentrations remained almost unchanged during the treatment process. Looking at Table 4.6 below, we find that some metals, such as copper, zinc, and nickel are even higher in SBR than the highest concentrations found in the two-stage system. Nonetheless, concentration in the final effluent water and sludge (see Table 4.7) in both systems remain well below the Dubai Municipality discharge standard (refer to appendix 4 for DM standards).

Table 4.6 Metals detected in wastewater in both SBR and acidogenesis phase of anaerobic/aerobic treatment plant

Metal	SBR (ppm)	Acidogenesis Phase (ppm)
Cu	0.18	0.06
Zn	0.69	0.22
Ni	0.14	0.02
Cr	<0.01	0.01
Pb	<0.01	0.02

Table 4.7 Metals detected in final sludge of both SBR and two-stage anaerobic/aerobic treatment plant

Metal	SBR (ppm)	Two-Stage System (ppm)
Cu	4.94	2.50
Zn	11.03	230.4
Ni	0.45	15.88
Cr	1.04	33.58
Pb	<0.01	20.1

The final effluent water quality results for both SBR and Two-Stage Anaerobic / Aerobic treatment plants are compared in Table 4.8 below. The final effluent seems to be cleaner than our two-stage system, but if we take into consideration the space occupied by each plan and the set-up costs involved, we find that both plants are efficient. Moreover, the SBR waste is treated to comply with marine discharge standard, which is more stringent than sewer discharge standard, to which the anaerobic / aerobic treatment system is treating.

Table 4.8 Comparison of final effluent water quality of SBR with two-stage anaerobic/aerobic treatment plant

Parameter	SBR (ppm)	Two-Stage System (ppm)
TSS	24*	45
TDS	2250*	1570
Oil & Grease	<1.0	22
BOD	12	98
COD	88	248
Cu	4.94	2.50
Zn	11.03	230.4
Ni	0.45	15.88
Cr	1.04	33.58
Pb	<0.01	20.1

* Values for treated water before sand filtration.

Chapter 5

Conclusions and Recommendations

The anaerobic / aerobic wastewater treatment technology for treating the effluent wastewater from a food plant in Dubai was evaluated. This wastewater treatment plant is operated under normal climate and controlled pH conditions. A two-phase anaerobic process has its advantages over a single phase as demonstrated in Chapter 2.

The following conclusions were drawn after analyzing and discussing the results: -

1. The two-phase continuous flow anaerobic treatment followed by activated sludge aerobic treatment proved to be especially suitable for UAE and Arabian Gulf climates. Since the heat of the inlet wastewater and the atmosphere is enough to provide an adequate treatment for the type of waste under investigation.

2. The treatment plant has been surveyed for two years under different loads and various seasonal and climatical conditions. The treatment plant has shown variations in performance depending on climate conditions and ambient temperatures. The anaerobic treatment stage was specifically sensitive to ambient temperature, as it performed much better in the hot seasons than in the cold season. This was obvious from the VOCs analysis, as the concentrations of VOCs detected in acidogenesis reactor in the summer was much higher than that detected in winter months.

3. Although the wastewater was purely organic industrial waste, some metal elements were detected in the system, which finally accumulated in the sludge. The metals were sourced back to pH controller and additive added during the treatment.

4. The preservation time for such wastewater has a great influence on the analysis results obtained. As degradation take place in the sample bottle even if the sample was kept chilled all the time. As chilling the sample might reduce the degradation rate, but does not stop it completely.

The results and conclusions reached in this thesis lead us to recommend the following: -

1. The biogas produced from the anaerobic digestion of wastewater could be used beneficially, by heating up the influent wastewater in order to reach the desirable thermophilic temperature. Since the biogas generation is directly related to organic loading, wastewater with high organic loads could be treated at thermophilic conditions, if biogas is effectively collected and used for influent temperature control.

2. Additives used in wastewater treatment must be carefully selected, since it could introduce inorganic impurities and metal toxins into the system and affect the treatment efficiency. These impurities at the end will have to end up in the sludge or in the treated water, affecting the final effluents quality.

3. When organic samples are collected for analysis, special care must be taken if the samples are to be transported for a long distance or stored before analysis. Samples could deteriorate easily leading to unsatisfactory results when analysis is finally carried out.

4. The preservation time for such wastewater need to be shortened as much as a researcher can to avoid misleading results.

5. The comparison made between the two-phase system and the SBR system lead us to recommend the two-phase system as an affordable substitute for treating high strength, low volume, and low consistency wastewater at situations when you have limited space and budget. While the SBR system is more adequate for low strength, high volume organic wastewater.

6. Future studies on two-stage anaerobic/aerobic plant with two-phase anaerobic treatment must take the following points into consideration: -

   (a) Complex composite samples must be collected and analyzed to verify our results and draw final conclusions.

   (b) Total analysis need to be conducted for all samples collected to better understand the process performance. This will be beneficial for further studies and developments.

   (c) Biogas measurement and analysis need to be considered, to evaluate the exact volumes of biogas released from anaerobic decomposition under these circumstances, and to find out the exact composition of the biogas.

References

Ahn, J.-H.; Forster, C.F. A Comparison of Mesophilic and Thermophilic Anaerobic Upflow filters Treating Paper-Pulp-Liquors, Process Biochemistry, **38**, 257-262, 2002.

Ahn, Y.; Min, K.; and Speece, R.E. Pre-acidification in anaerobic sludge bed process treating brewery wastewater. Water Res., 35, 4267, 2001.

Alexiou, I.E.; Anderson, G.K.; and Evision, L.M. *Design of Pre-Acidification Reactors for the Anaerobic Treatment of Industrial Wastewater,* Water Science and Technology, **29(9)**, 199-204, 1994.

Armenante P. M. et al. *Anaerobic-Aerobic Treatment of Hallogenated Phenolic Compounds,* Water Research, **33(3)**, 681-692, 1999.

Azbar, N.; and Speece, R.E. *Two-Phase, Two-Stage, and Single-Stage Anaerobic Process Comparison,* J. Environmental Engineering, J. Environmental Engineering, March, 240-248, 2001

Barker, W.P.; and D.C. Stuckey, *The Use of the Anaerobic Baffled Reactore (ABR) for Wastewater Treatment: A Review,* Water Research, **33 (7)**, 1559-1578, 1999a.

Barker, W.P.; and D.C. Stuckey, *A Review of Soluble Microbial Products (SMP) in Wastewater Treatment Systems,* Water Research, **33**, 3063-3071, 1999b.

Barker, W.P.; and D.C. Stuckey, *Modelling of Soluble Microbial Products in Anaerobic Digestion: The Effect of Feed and Composition,* Water Environmental Research, **73**, 173-184, 2001.

Bello-Mendoza, R.; and Sharratt, P.N. *Modelling the Effect of Imperfect Mixing on the Performance of Anaerobic Reactors for Sewage Sludge Treatment,* Journal of Chemistry Technology nnd Biotechnology, **71(2)**, 121, 1998.

Bodik, I.; Herdova, B.; Drtil, M. *The use of Upflow anaerobic filter and AnSBR for Wastewater Treatment at Ambient Temperature,* Water Research, **36**, 1084-1088, 2002.

Borja, R.; and Banks, C.J. *Anaerobic Digestion of Ice-Cream Wastewater: A Comparison of Single and Two-Phase Reactor Systems,* Bulletin of Enironmental Research and Toxicology, **54**, 466-471, 1995.

Borup, M.B.; Muchmore, D.R. *Food Processing Waste,* Water Environmental Research, **64(4)**, 413-417, 1992.

Breuer, A.M.; and Van Andel, J,G. *Hydrolysis and Acidogenic Fermintation of a Protien Gelatin in an Anaerobic Continuous Culture,* J. Applied Microbiology and Biotechnology, **20(1)**, 40-45, 1984.

Breuer, A.M.; Van Andel, J,G.; and Burger-Wiersma, T. *The Anaerobic Acidification of Gelatin in Continuous Culture by a Mixed Population Bacteria,* Journal of Mocrobiology, **50(1)**, 78, 1984.

Codina, J.C.; Munoz, A.M.; and Cazorla F.M. *The Inhibition of Methanogenic Activity form Anaerobic Domestic Sludge as a Simple Toxicity Bioassy,* Water Research (G.B.), **32**, 1338, 1998.

Dinopoulou, G.; Rudd, T.; and Lester J.N. *Anaerobic Acidogenesis of a complex Waste-water, I. The Influence of opration Parameters on Reactor Performance,* Biotechnology and Bioengineering, **31(9)**, 958-968, 1988.

Dubai Municipality Drainage and Irrigation Department. *History and Achievements,* Handbook, 1998.

Duff, S.J.B.; and Kennedy, K.J. *Effect of Hydraulic and Organic Overloading on Thermophilic Downflow Dtationary Fixed Film (DSFF) Reactor,* Biotechnology Letters, **4(12)**, 815-820, 1982.

Duff, S.J.B.; and Van Den Berg, L. *Treatment of Fish Processing Waste Using the Downflow Stationary Fixed Film (DSFF) Reactor,* Biotechnology Letters, **4(12)**, 821-826, 1982.

Eckenfelder, W.W. *Industrial Water Pollution Control*, McGraw Hill, 2000.

Ellis, T.G.; Eliosov, B.; Schmit, C.G.; Jahan, K.; and Park, K.Y. Activated Sludge and Other Aerobic Suspended Culture Processes, Water Environmental Research, 74, 385-410, 2002.

Fels, M.; Pinter, J.; Lycon, D.S. Optimized Design of Wastewater Treatment Systems: Application to the Mechanical Pulp and Paper Industry: I. Design and Cost Relationships., Canadian J. of Chemical Engineering, **75**, 437-451, 1997.

Fernandez, J.M.; Mendez, R.; Lema, J.M. Anaerobic *Treatment of Eucalyptus Fibreboard Manufacturing Wastewater by Hybrid USBF Lab Scale Reactor*, Environmental Technology, **16**, 677-684, 1995.

Grismer, M.E.; Ross, C.C.; Valentine, G.E.; Smith, B.M.; and Walsh, J.L. Food Processing Wastes, Water Environmental Research, 74, 377-384, 2002.

Guerrero, L.; Omil, F.; Mendez R.; and Lema, J.M. *Anaerobic Hydrolysis and Acidogenesis of Wastewaters from Food Industries with High Content of Organic Solids and Protein,* Water Research, **33(15)**, 3281-3290, 1999.

Heijnen, S.J.; Mulder, A.; Welreverde, R.; Hols, P.H.; Van Leeuwen, L.M.J. *Large-scale Anaerobic/Aerobic Treatment of Complex Industrial Wastewater Using Immobilized Biomass in Fluidizing Bed and Air-lift Suspension Reactors,* Chemical Eng. Tech.., **13**, 202-208, 1990.

Hulshoff Pol L.W.; Euler, H.; Eitner, A.; Grohganz, D. GTZ serial project "*Promotion ofAnaerobic Technology for the Treatment of Municipal and Industrial Sewage and waste*", Proceedings of the Eighth Intr. Conf. On Anaerobic Digestion. Dec., 6th-7th, Narbonne, France, 1995.

Ishino, Y.; Komori, K; Cann, I.K.; and Okoga, Y. *A Novel DNA Polymerase Family in Archaea*, Journal of Bacteriol, **180(8)**, 2232, 1998.

Kaare, Hvid Hansen et al. *Improving Thermophilic Anaerobic Digestion of Swine Manure*, Water Research, **33(8)**, 1805-1810, 1999.

Kuo, W.C.; Sneve, M.A.; Parkin, G.F. *Formation of Soluble Microbial Products During Anaerobic Treatment*, Water Environmental Research, **68**, 279-285, 1996.

Lapara, T. M.; and Alleman J. E. *Thermophilic Aerobic Biological Wastewater Treatment*, Water Research, **33(4)**, 895-908, 1999.

Londry, K.L.; and Suflita, J.M. *Toxicity Effects of Organosulfur Compounds on Anaerobic Microbial Metabolism*, Environment Toxicology and Chemistry, **17(7)**, 1199, 1998.

Mata-Alvarez, J. *A Dynamic Simulation of a Two-Phase Anaerobic Digestion System for Solid Wastes*, Biotechnology and Bioengineering, **30**, 844-851, 1987.

Moletta, R.; Verhir, D.; and Albagnac, G. *Dynamic Modelling of Anaerobic Digestion*, Water Research, **20(4)**, 427-434, 1986.

Mosey, F.E. *Mathematical Modelling of the Anaerobic Digestion Process: Regulatory Mechanisms for the Formation of Short-Chain Volatile Acids from Glucose*, Water Science and Technology, **15**, 209-232, 1983.

Ng, W.J.; Hu, J.Y.; Ong, S.L.; and Aziz, M.A. *Effect of Acidogenic Stage on Aerobic Toxic Organic Removal*, Journal of Environmental Engineering, 495-500, 1999.

Obayashi, A.W.; Gorgan, J.M. Management of Industrial Pollutants by Anaerobic Processes, Lewis Publishers, Chelsea, Mich., 1985.

Perez, M.; Romero, L.I.; and Sales, D. *Comparative Performance of High Rate Anaerobic Thermophilic Technologies Teating Industrial Wastewater*, Water Research, **32(3)**, 559-564, 1998.

Perez, M.; Romero, L.I.; and Sales, D. Organic Matter Degradation Kinetics in an anaerobic Thermophilic Fluidized Bed Bioreactor, Anaerobe, 7, 1, 25, 2001

Perez, M.; Romero, L.I.; and Sales, D. Kinetics of Thermophilic Anaerobes in Fixed Bed Reactor, Chemosphere, 44, 1201, 2001

Punal, A.; Roca, E.; Lema, J.M. *An Expert System for Monitoring and Diagnosis of Anaerobic Wastewater Treatment Plants*, Water Research, **36**, 2656-2666, 2002

Riggle, D. *Anaerobic Digestion for MSW and Industrial Wastewater*, BioCycle, 37(11), 1-5, 1996.

Riffat R.; Dararat, S.; and Krogthamchat, K. *Anaerobic Processes*, Water Environment Research, 71(5), 656-676, 1999.

Riffat R.; Sajjad, M.W.; and Dararat, S. *Anaerobic Processes*, Water Environment Research, 70(4), 518-540, 1998.

Sivathanu, S. R.; and Kasturi Bai, R. *Anaerobic Digestion of Wastewater from Unhairing and Defleshing Operations of Tannery*, Journal of Industrial Pollution Control, 14(1), 55-58, 1998.

Speece, R.E. *Anaerobic Biotechnology for Industrial Wastewaters*, Archae Press, Nashville, TN, 1996.

Stronach, S.M.; Rudd, T.; Lester J.N. *Anaerobic Digestion Processes in Industrial Wastewater Treatment*, Berlin, Springer, 1986.

Suidan, M.T.; Wang, Y.T. *Unified Analysis of Biofilm Kinetics*, J. Environmental Engineering, 111, 634-642, 1985 .

Sung, S.; and Dague R. *Laboratory Studies on the Anaerobic Sequencing batch Reactor*, Water Environment Research, 67(3), 294-301, May/June 1995.

Switzenbaum, M.S. *Anaerobic Biotechnology for Industrial Wastewaters*, USA, Archae Press, 1995.

Tay, Joo-Hwa; and Zhang, X. *Stability of High Rate Anaerobic Systems, I: Performance Under Shocks*, Journal of Environemtal Engineering, 713-724, Agusut 2000.

Tay, Joo-Hwa; and Zhang, X. *Stability of High Rate Anaerobic Systems, II: Fuzzy Stability Index*, Journal of Environemtal Engineering, 726-731, Agusut 2000.

Tay, Joo-Hwa et al. *Improved Anaerobic Degradation of Phenol with Supplemental Glucose*, Journal of Environmental Engineering, pp. 38-45, January, 2001.

Terzis, E. *Anaerobic Treatment of Industrial Wastewater Containing Organic Solvents*, Water Science & Technology, 29(9), 321-329, 1994.

Thomas, M.V.; and Nordstedt, R.A. *Generic Anaerobic Digestion Model for the Simulation of Various Reactor Types and Substrates*, ASAE, 36(2), 537-544, March-April 1993.

Westlund, A.D.; Hagland, E.; and Rothamn M. *Foaming in Anaerobic Digesters Caused by Microthrix Parvicella*, Water Science and Technology (G.B.), 37, 4-5 and 51, 1998.

Wilson, F.; Yu, H. Joo-Hwa Tay, J.-H.; and Gu, G. *An Empirical Model for Prediction of Organic Concentration of Anaerobic Filter Effluents.* Water Environment Research, **70(3)**, 299-305, 1998.

Yu, H.-Q.; Fang, H.H.P.; G.-W. Comparative Performance of Mesophilic and Thermophilic Acidogenic Upflow Reactors, Process Biochemistry, **38**, 447-454, 2002

Appendix 1

Wastewater Analysis Results

Central Laboratories Unit
UAE University

Results of Waste water

Sample ID	Propionic Acid (mg/L)[2]	Butyric Acid (mg/L)[2]	Valeric Acid (mg/L)[2]	Hexanoic Acid (mg/L)[2]	Heptanoic Acid (mg/L)[2]	Total Fats (mg/L)	% Protein	% Sugers[1]
Sample point # 1 24/12 @ 1:30 PM	0.133	<IDL	<IDL	0.07	<IDL	70.00	0.011	<MDL
Sample point # 1 chilled sample	0.184	<IDL	<IDL	0.07	<IDL	80.00	0.013	<MDL
Sample point # 2 24/12 @ 1:30 P.M.	2.020	11.79	45.25	25.54	5.18	180.00	0.031	<MDL
Sample point # 2 chilled sample	2.16	12.82	46.27	24.89	4.83	200.00	0.036	<MDL
Sample point # 3 24/12 @ 1:30 P.M Methane	0.127	<IDL	<IDL	<IDL	<IDL	10.00	0.054	<MDL
Sample point # 3 24/12 @ 1:30 P.M Methane	0.085	<IDL	<IDL	<IDL	<IDL	10.00	0.053	<MDL
Sample point # 5 24/12@ 1:30 P.M Methane	0.252	<IDL	<IDL	<IDL	<IDL	17.90	0.055	<MDL
Sample point # 4 24/12 @ 1:30 P.M Final Tank	0.155	<IDL	<IDL	<IDL	<IDL	3.10	0.008	<MDL

1.Method Detection Limit (MDL) for Sugers is 0.2%

2.Istrument Detection Limit (IDL) of the applied method for fatty acids in water is 0.07 mg/L

Central Laboratories Unit
UAE University

Results of Metals in Waste water

Sample ID	Al	Ba	Cd	Cr	Cu	Ni	Pb	Zn
Sample point # 1 24/12 @ 1:30 PM	157.01	27.12	*< MDL	5.79	22.65	10.09	*< MDL	57.96
Sample point # 1 chilled sample	129.75	33.48	*< MDL	9.80	25.93	10.02	*< MDL	86.48
Sample point # 2 24/12 @ 1:30 P.M.	157.83	28.18	*< MDL	4.96	27.07	14.09	*< MDL	159.78
Sample point # 2 chilled sample	144.62	26.33	*< MDL	5.14	27.12	14.06	*< MDL	40.13
Sample point # 3 24/12 @ 1:30 P.M Methane	2336.60	14.36	*< MDL	*< MDL	18.96	6.65	*< MDL	40.13
Sample point # 3 24/12 @ 1:30 P.M Methane	2007.00	13.51	*< MDL	*< MDL	6.54	4.32	*< MDL	35.96
Sample point # 5 24/12@ 1:30 P.M Methane	20.62	18.22	*< MDL	*< MDL	15.72	5.49	*< MDL	44.41
Sample point # 4 24/12 @ 1:30 P.M Final Tank	*< MDL	0.75	*< MDL	*< MDL	4.44	8.16	*< MDL	11.80
Method Detection Limits	*2.0*	*0.5*	*2.0*	*4.0*	*2.0*	*1.3*	*2.0*	*0.3*

Note: 1. All units are in μg/l 2. Less than Method Detection Limit (MDL) 3. All Method Detection Limits are in μg/l.*

Central Laboratories Unit
UAE University

Results of Waste water

Sample ID	Propionic Acid (mg/L)[2]	Butyric Acid (mg/L)[2]	Valeric Acid (mg/L)[2]	Hexanoic Acid (mg/L)[2]	Heptanoic Acid (mg/L)[2]	Total Fats (mg/L)	% Protein[3]	% Sugers[1]
Sample point # 1-A 22/3 @ 1:00 PM	0.090	<IDL	<IDL	<IDL	<IDL	249.60	0.020	<MDL
Sample point # 1-B 22/3 @ 1:00 PM	0.093	<IDL	<IDL	<IDL	<IDL	254.00	0.023	<MDL
Sample point # 2-A 22/3 @ 1:00 PM	0.540	3.08	6.28	2.60	0.39	89.00	0.012	<MDL
Sample point # 2-B 22/3 @ 1:00 PM	0.53	3.12	6.43	2.67	0.40	87.50	0.009	<MDL
Sample point # 3-A 1:00 PM Methane outlet	0.060	<IDL	<IDL	<IDL	<IDL	5.80	0.0008	<MDL
Sample point # 3-B 1:00 PM Methane outlet	0.070	<IDL	<IDL	<IDL	<IDL	6.10	0.00097	<MDL
Final Tank Sample point # 4-A 22/3 @ 1:00 PM	<IDL	<IDL	<IDL	<IDL	<IDL	2.10	<MDL	<MDL
Final Tank Sample point # 4-B 22/3 @ 1:00 PM	<IDL	<IDL	<IDL	<IDL	<IDL	1.90	<MDL	<MDL

1.Method Detection Limit (MDL) for Sugers is 0.2%

2.GC Istrument Detection Limit (IDL) of the applied method for fatty acids in water is 0.07 mg/L

3.Method Detection Limit (MDL) for Protein by titrimetry is 0.0006%

Central Laboratories Unit
UAE University

Results of Metals in Waste water

Sample ID	Al	Ba	Cd	Cr	Cu	Ni	Pb	Zn
Sample point # 2-A 22/3 @ 1:00 PM	385.87	168.86	7.94	11.56	51.49	18.04	7.25	327.34
Sample point # 2-B 22/3 @ 1:00 PM	387.66	169.50	7.50	11.98	52.01	18.75	7.34	326.94
Final Tank Sample point # 4-A 22/3 @ 1: 00 PM	144.62	205.84	1.57	4.55	8.93	13.67	2.06	83.10
Final Tank Sample point # 4-B 22/3 @ 1: 00 PM	145.98	203.49	1.34	4.90	8 49	13.50	2.18	82.98
Sample point # 1-A 22/3 @ 1:00 P.M.	554.35	173.82	1.85	9.06	48.96	12.66	8.87	824.30
Sample point # 1-B 22/3 @ 1:00 P.M.	553.39	171.89	1.89	8.96	49.30	12.20	8.50	826.69
Sample point # 3-A 1:00 PM Methane outlet	456.67	113.27	2.42	12.89	55.97	19.24	8.20	213.44
Sample point # 3-B 1:00 PM Methane outlet	457.20	112.98	2.88	12.20	54.09	19.39	8.29	212.93
Instrument Detection Limits	2.0	0.5	2.0	4.0	2.0	1.3	2.0	0.3

Note: 1. All units are in μg/l

18/6/2001

Central Laboratories Unit
UAE University

Results of Waste water

Sample ID	Propionic Acid (mg/L) [2]	Butyric Acid (mg/L) [2]	Valeric Acid (mg/L) [2]	Hexanoic Acid (mg/L) [2]	Heptanoic Acid (mg/L) [2]	Total Fats (mg/L)	Oil&Grease (mg/L) [4]	% Sugars [1]	TKN (mg/L) [3]	Free Ammonia
Sample point # 1-A 16/6 @ 12:00 AM Inflow Waste	0.200	0.34	0.65	0.31	0.28	348.20	11.60	<MDL	4.03	1.15
Sample point # 1-B 16/6 @ 12:00 AM Inflow Waste	0.224	0.32	0.69	0.39	0.24	321.90		<MDL	3.74	1.14
Sample point # 2-A 16/6 @ 12:00 AM Preacidification Tank	2.590	23.18	48.26	23.50	4.01	95.70	6.10	<MDL	7.25	1.05
Sample point # 2-B 16/6 @ 12:00 AM Preacidification Tank	2.62	22.51	47.39	23.80	3.35	116.60		<MDL	5.80	1.00
Sample point # 3-A 16/6 12:00 AM Methanation Tank	0.132	<IDL	<IDL	0.129	<IDL	8.00	<MDL	<MDL	107.95	90.60
Sample point # 3-B 16/6 12:00 AM Methanation Tank	0.120	<IDL	<IDL	0.125	<IDL	7.10		<MDL	109.23	91.00
Final Tank Sample point # 4-A 16/6 @ 12:00 AM	<IDL	<IDL	<IDL	<IDL	<IDL	1.60	<MDL	<MDL	2.04	1.05
Final Tank Sample point # 4-B 16/6 @ 12:00 AM	<IDL	<IDL	<IDL	<IDL	<IDL	1.40		<MDL	2.23	1.10

1. Method Detection Limit (MDL) for Sugars is 0.2%.
2. GC Istrument Detection Limit (IDL) of the applied method for fatty acids in water is 0.07 mg/L.
3. Total Kjeldahl Nitrogen (TKN) for Total Nitrogen is carried out by titrimetry.
4. Method Detection Limit (MDL) for Oil&Grease in Water is 1.6 mg/L.

Central Laboratories Unit
UAE University

17/11/2001

Results of Waste water

Sample ID	Propionic Acid (mg/L)[1]	Butyric Acid (mg/L)[1]	Valeric Acid (mg/L)[1]	Hexanoic Acid (mg/L)[1]	Heptanoic Acid (mg/L)[1]	Total Fats (mg/L)	Oil&Grease (mg/L)[3]	Total Protein (%)	TKN (mg/L)[2]	Free Ammonia, ppm
175/S-sample point # 1-A/Chrom/AAS/ICP/200	0.16	0.28	0.53	0.42	0.25	300.60	9.80	0.004	6.90	0.07
175/S-sample point # 1-B/Chrom/AAS/ICP/200	0.14	0.27	0.50	0.39	0.23	298.30	9.10	0.005	7.60	
175/S-sample point # 2-A/Chrom/AAS/ICP/200	1.85	13.71	31.94	13.04	4.72	86.90	7.30	0.041	64.90	0.04
175/S-sample point # 2-B/Chrom/AAS/ICP/200	1.89	13.49	30.60	12.99	4.71	90.50	6.50	0.038	60.40	
175/S-sample point # 3-A/Chrom/AAS/ICP/200	0.11	0.08	0.09	0.13	<IDL	6.40	<MDL	0.092	146.60	126.00
175/S-sample point # 3-B/Chrom/AAS/ICP/200	0.13	0.09	0.10	0.14	<IDL	5.20	<MDL	0.087	139.10	
175/S-sample point # 4-A/Chrom/AAS/ICP/200	<IDL	<IDL	<IDL	<IDL	<IDL	ND	<MDL	0.002	3.20	45.00
175/S-sample point # 4-B/Chrom/AAS/ICP/200	<IDL	<IDL	<IDL	<IDL	<IDL	ND	<MDL	0.002	2.89	

1. GC Method Detection Limit (MDL) of the applied method for fatty acids in water is 0.07 mg/L.
2. Total Kjeldahl Nitrogen (TKN) for Total Nitrogen is carried out by titrimetry.
3. Method Detection Limit (MDL) for Oil&Grease in Water is 1.6 mg/L.

Central Laboratories Unit
UAE University

Results of Metals in Waste water 17/11/2001

Sample ID	Al	Ba	Cd	Cr	Cu	Ni	Pb	Zn
0175/S-1-Chrom/AAS/ICP/2001	178.10	33.60	< 2.0	7.20	15.00	8.90	5.10	54.60
0175/S-2-Chrom/AAS/ICP/2001	278.50	45.50	< 2.0	11.10	63.00	21.30	24.60	215.00
0175/S-3-Chrom/AAS/ICP/2001	123.10	26.30	< 2.0	4.20	33.30	12.80	19.60	108.00
0175/S-4-Chrom/AAS/ICP/2001	15.10	7.20	< 2.0	1.40	< 2.0	9.20	1.80	20.40
0175/S-Urea-Chrom/AAS/ICP/2001	84.30	11.49	< 2.0	55.85	29.71	41.62	11.46	41.86
0175/S-Sodium Hydroxide-Chrom/AAS/ICP/2001	191.21	17.15	< 2.0	40.59	87.01	125.41	213.91	112.28
Instrument Detection Limits	*2.0*	*0.5*	*2.0*	*4.0*	*2.0*	*1.3*	*2.0*	*0.3*

Note: 1. All units are in μg/l

AL HOTY - STANGER LABORATORIES
Independent Testing Laboratories
and Materials Consultants

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
مستشار ومواد

TEST REPORT

CLIENT **RENTEC**

ANALYSIS OF WASTE WATER

Report No.	: DR-76131	Report date	:	17/04/2000
Sample No.	: DS-048271	Sample container	:	Plastic bottle
Name & designation of sampling officer	: Rentec Rep.	Sample appearance	:	Hazy
Client's Description		Sample received on time	:	11/04/2000 / 1400 Hrs.
Purpose of sampling	: Quality purpose			
Name & location of sampled premises	: Seville Products, Al Quoz	Test method	:	Standard Method for the Examination of Water & Waste Water, APHA/AWWA/WEF, 20th Edition
Precise sampling location	: Final tank			
Date & time of sampling	: 11/04/200 / 0930 Hrs.			
Sampling method	: Not given	Test dates	:	11/04/2000 to 16/04/2000
Temp. of the sample	: Not given			
On-site treatment	: Not given			

Results :

parameters		test method	Results
pH at 25°C		APHA 4500 – H^+B	8.69
Total Suspended Solids	(TSS)	" 2540 – D	34
Total Dissolved Solids at 180°C	(TDS)	" 2540 – C	3140
Oil & Grease	(Emulsified)	" 5520 – B	8
Chemical Oxygen Demand	(COD)	" 5220 – B	524
Bio Chemical Demand (5 days) at 20°C		" 5210 – B	160
Ammonia Nitrogen (NH_3 – N)		" 4500 – NH3 B & C	1.6
Phosphate – Phosphorus (PO_4 – P)		" 4500 – P.C	1.9
METALS (ATOMIC ABSORPTION SPECTROMETRY)			
Copper	(Cu)	APHA 3500 – Cu B	0.04
Nickel	(Ni)	" 3500 – NaB	LT 0.01
Zinc	(Zn)	" 3500 – Zn B	0.03
Chromium	(Cr)	" 3500 – Cr B	LT 0.01
Lead	(Pb)	" 3500 – Pb B	LT 0.01
Manganese	(Mn)	" 3500 – Mn B	LT 0.01
Cadmium	(Cd)	" 3500 – Cd B	LT 0.01

Remarks : None
Results in mg/L where appropriate.
Test method variation : None
This test is not accredited by Dubai Municipality
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories.

Head of Chemistry Section
For Al Hoty Stanger Laboratories

mm

ص.ب ١٦٧٥٦ ، دبي ، إ.ع.م.، تليفون: (٠٤) ٣٤٧٢٢٠١ ، فاكس: (٠٤) ٣٤٧٢٧٢٧
P. O. BOX 16756, DUBAI, U. A. E., TEL. : (04) 3472201, FAX : (04) 3472727
E-Mail : alhoty@emirates.net.ae

L HOTY - STANGER LABORATORIES
ndependent Testing Laboratories
nd Materials Consultants

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

TEST REPORT

CLIENT **SEVILLE PRODUCTS LTD. (AL QUOZ)**

ANALYSIS OF WASTE WATER

Report No.	:	DR-88745	Report date	:	06/07/2000
Sample No.	:	DS-059338	Sampling method	:	ASTM D 3370 : 1995
Name & designation of sampling officer	:	AHS Rep. in presence of Seville Products Rep.			
Purpose of sampling	:	Permit compliance	Sample container	:	1 L. Plastic bottle
Name & location of sampled premises	:	Seville Products premises Al Quoz	Sample appearance	:	Hazy
Precise sampling Location	:	After water treatment, Final tank			
Date	:	31/07/2000	Test method	:	Standard Method for the Examination of Water & Waste Water, APHA/AWWA/WEF, 20th Edition
Time	:	1600 Hrs.			
Temperature	:	40°C			
On-site treatment	:	Sample transported in ice box	Test dates	:	31/07/2000 to 05/07/2000

Results :

PARAMETERS		TEST METHOD	RESULTS
pH at 25°C		*APHA 4500 – H⁺B*	8.89
Total Suspended Solids	(TSS)	*" 2540 – D*	45
Total Dissolved Solids at 180°C	(TDS)	*" 2540 – C*	1570
Oil & Grease	(Emulsified)	*" 5520 – B*	22
Chemical Oxygen Demand	(COD)	*" 5220 – B*	248
Biochemical Oxygen Demand (5 days @ 20°C)	(BOD)	*" 5210 – B*	98
METALS (ATOMIC ABSORPTION SPECTROMETRY)			
Copper	(Cu)	*APHA 3111 – B & C*	0.03
Nickel	(Ni)	"	LT 0.01
Zinc	(Zn)	"	0.07
Chromium	(Cr)	"	LT 0.01
Lead	(Pb)	"	LT 0.01
Manganese	(Mn)	"	0.04
Cadmium	(Cd)	"	0.01

LT : Less than
Results in mg/L where appropriate.
Test method variation : None
This test is not accredited by Dubai Municipality
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories.

Christopher

Head of Chemistry Section
For Al Hoty Stanger Laboratories

mVrm

ص.ب ١٦٧٥٦ ، دبي ، ا.ع.م.، تليفون: ٣٤٧٢٢٠١ (٠٤) ، فاكس : ٣٤٧٢٧٢٧ (٠٤)
P. O. BOX 16756, DUBAI, U. A. E., TEL. : (04) 3472201, FAX : (04) 3472727
E-Mail : alhoty@emirates.net.ae

FS 45701 003
ISO 9002 CERTIFIED

L HOTY - STANGER LABORATORIES
ndependent Testing Laboratories
nd Materials Consultants

TEST REPORT

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

CLIENT **SEVILLE PRODUCTS (AL QUOZ)**

ANALYSIS OF WASTE WATER

Report No.	:	DR-90594	Report date	:	22/08/2000
Sample No.	:	DS-060843	Sampling method	:	ASTM D 3370 : 1995
Name & designation of sampling officer	:	AHS Rep. in presence of Seville Products Rep.			
Purpose of sampling	:	Permit compliance	Sample container	:	Plastic bottle
Name & location of sampled premises	:	Seville Products premises Al Quoz	Sample appearance	:	Hazy
Precise sampling Location	:	Final Wastewater tank			
Date	:	16/08/2000	Test method	:	Standard Method for the Examination of Water & Waste Water, APHA/AWWA/WEF, 20th Edition
Time	:	1530 Hrs.			
On-site treatment	:	Sample transported in ice box	Test dates	:	16/08/2000 – 21/08/2000

Results :

PARAMETERS		TEST METHOD	RESULTS
pH at 25°C		*APHA 4500 – H^+B*	8.62
Total Suspended Solids	(TSS)	" *2540 – D*	46
Total Dissolved Solids at 180°C	(TDS)	" *2540 – C*	280
Oil & Grease	(Emulsified)	" *5520 – B*	24
Chemical Oxygen Demand	(COD)	" *5220 – B*	560
Biochemical Oxygen Demand (5 days @ 20°C)	(BOD)	" *5210 – B*	220
METALS (ATOMIC ABSORPTION SPECTROMETRY)			
Copper	(Cu)	*APHA 3111 – B & C*	0.04
Nickel	(Ni)	"	LT 0.01
Zinc	(Zn)	"	0.06
Chromium	(Cr)	"	0.08
Lead	(Pb)	"	0.29
Manganese	(Mn)	"	LT 0.01
Cadmium	(Cd)	"	LT 0.01

LT : Less than
Results in mg/L where appropriate.
Test method variation : None
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories.

الحوطي ستانجر
AL HOTY-STANGER

Head of Chemistry Section
For Al Hoty Stanger Laboratories

rl\/rm

ص.ب ١٦٧٥٦ ، دبي ، ا.ع.م.، تليفون: ٣٤٧٢٢٠١ (٠٤) ، فاكس: ٣٤٧٢٧٢٧ (٠٤)
P. O. BOX 16756, DUBAI, U. A. E., TEL. : (04) 3472201, FAX : (04) 3472727
E-Mail : alhoty@emirates.net.ae

L HOTY - STANGER LABORATORIES
ndependent Testing Laboratories
nd Materials Consultants

TEST REPORT

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

CLIENT **SEVILLE PRODUCTS LTD (AL QUOZ)**

ANALYSIS OF WASTE WATER

Report No.	:	DR-93798	Report date	:	23/09/2000
Sample No.	:	DS-063489	Sampling method	:	ASTM D 3370 : 1995
Name & designation of sampling officer	:	AHS Rep. in presence of Seville Products Rep.			
Purpose of sampling	:	Permit compliance	Sample container	:	1 L. Plastic bottle
Name & location of sampled premises	:	Seville Products premises, Al Quoz	Sample appearance	:	Hazy
Precise sampling location	:	Final wastewater tank (After treatment)	Test method	:	Standard Methods for the Examination of Water & Wastewater APHA/AWWA/WEF; 20th Edition
Date	:	17/09/2000			
Time	:	1030 Hrs			
Temperature	:	35°C			
On-site treatment	:	Sample transported in ice box	Test dates	:	17/09/2000 to 22/09/2000

Results :

PARAMETERS		TEST METHOD	RESULTS
pH at 25°C		*APHA 4500 – H⁺B*	8.52
Total Suspended Solids	(TSS)	" *2540 – D*	296
Total Dissolved Solids at 180°C	(TDS)	" *2540 – C*	2520
Oil & Grease	(Emulsified)	" *5520 – B*	18
Chemical Oxygen Demand	(COD)	" *5220 – B*	728
Biochemical Oxygen Demand (5 days @ 20°C)	(BOD)	" *5210 – B*	430
METALS (ATOMIC ABSORPTION SPECTROMETRY)			
Copper	(Cu)	*APHA 3111 – B & C*	0.05
Nickel	(Ni)	"	0.07
Zinc	(Zn)	"	0.15
Chromium	(Cr)	"	0.12
Lead	(Pb)	"	LT 0.01
Manganese	(Mn)	"	0.08
Cadmium	(Cd)	"	LT 0.01

LT : Less than
Results in mg/L where appropriate.
Test method variation : None
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories.

Head of Chemistry Section
For Al Hoty Stanger Laboratories

/rm

ص.ب ١٦٧٥٦ ، دبي ، ا.ع.م. ، تليفون: ٣٤٧٢٢٠١ (٠٤) ، فاكس : ٣٤٧٢٧٢٧ (٠٤)
P. O. BOX 16756, DUBAI, U. A. E., TEL. : (04) 3472201, FAX : (04) 3472727
E-Mail : alhoty@emirates.net.ae

ISO 9002 CERTIFIED

HOTY - STANGER LABORATORIES
Independent Testing Laboratories
and Materials Consultants

TEST REPORT

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

CLIENT - SEVILLE PRODUCTS LTD. (AL QUOZ)

ANALYSIS OF WASTE WATER

Report No.	:	DR-99770	Report date	:	25.11.2000
Sample No.	:	DS-068716	Sampling method	:	ASTM D 3370 : 1995
Name & designation of sampling officer	:	AHS Rep. In presence of Seville Products Rep.			
Purpose of sampling	:	Permit compliance	Sample container	:	1 L Plastic bottle
Name & location of sampled premises	:	Seville Products premises, Al Quoz	Sample appearance	:	Hazy
Precise sampling location	:	Final waste water tank			
Date	:	19.11.2000	Test method	:	Standard Methods for the Examination of Water & Waste Water, APHA/AWWA/WEF, 20th Edition
Time	:	1700 Hrs.			
On-site treatment	:	Sample transported in ice box	Test dates	:	19.11.2000 – 24.11.2000

Results :

PARAMETERS		TEST METHOD	RESULTS
pH at 25°C		*APHA 4500 – H⁺B*	7.41
Total Suspended Solids	(TSS)	" *2540 – D*	210
Total Dissolved Solids at 180°C	(TDS)	" *2540 – C*	1310
Oil & Grease	(Emulsified)	" *5520 – B*	28
Chemical Oxygen Demand	(COD)	" *5220 – B*	2560
Biochemical Oxygen Demand (5 days @ 20°C)	(BOD)	" *5210 – B*	920
METALS (ATOMIC ABSORPTION SPECTROMETRY)			
Copper	(Cu)	*APHA 3111 –CuB*	0.05
Nickel	(Ni)	" *3111 –NiB*	0.27
Zinc	(Zn)	" *3111 –ZnB*	0.14
Chromium	(Cr)	" *3111 –CrB*	0.63
Lead	(Pb)	" *3111 –PbB*	LT 0.01
Manganese	(Mn)	" *3111 –MnB*	0.08
Cadmium	(Cd)	" *3111 –CdB*	LT 0.01

LT : Less than
Results in mg/L where appropriate.
Test method variation : None.
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories.

Head of Chemistry Section
Al Hoty Stanger Laboratories

AL HOTY-STANGER

ص.ب ١٦٧٥٦ ، دبي ، إ.ع.م ، تليفون : ٣٤٧٢٢٠١ (٠٤) ، فاكس : ٣٤٧٢٧٢٧ (٠٤)
P. O. BOX 16756, DUBAI, U. A. E., TEL. : (04) 3472201, FAX : (04) 3472727
E-Mail : alhoty@emirates.net.ae

Appendix 2

Sludge Analysis Results

AL HOTY - STANGER LABORATORIES
Independent Testing Laboratories
and Materials Consultants

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

TEST REPORT

CLIENT SEVILLE PRODUCTS LTD (AL QUOZ)

ANALYSIS OF SLUDGE SAMPLE

Report No.	:	DR-92854	Report date	:	16/09/2000
Sample No.	:	DS-062741	Sampling method	:	Composite
Name & designation of sampling officer	:	AHS Rep. in presence of Seville Products Rep.			
Purpose of sampling	:	Permit compliance	Sample container	:	Plastic bag
Name & location of sampled premises	:	Seville Products premises, Al Quoz			
			Sample appearance	:	Black coloured sludge
Precise sampling location	:	Final waste from treatment plant			
Date	:	09/09/2000	Test method	:	1. Standard Methods of Chemical Analysis F.J., Welcher 2. D.M's E.P.S.S. T.G.L.#23 3 Atomic Absorption Spectrometry. 4. Standard Methods for the Examination of Water & Wastewater APHA/AWWA/WEF: 20th Edition
Time	:	0930 Hrs			
On-site treatment	:	Sample transported in ice box	Test dates	:	09/09/2000 to 14/09/2000

Results :

Parameters	Results	
pH at 35°C (1:1 water extract)	6.81	
Conductivity at 25°C (1:5 water extract)	256	
Moisture, % by weight	10.8	
Organic matter at 550°C, % by weight	76.7	
Oil & grease (solvent extraction), mg/kg	4368	
Chemical Oxygen Demand (COD), mg/kg	328000	
Biochemical Oxygen Demand (BOD), (5 days @ 20°C)	198000	
METALS (ATOMIC ABSORPTION SPECTROMETRY)		
Parameters	Leachable Fraction (mg/kg)	Total Concentration (mg/kg)
Copper (Cu), mg/kg	LT 0.01	2.50
Nickel (Ni), mg/kg	LT 0.01	15.88
Chromium (Cr), mg/kg	LT 0.01	33.58
Lead (Pb), mg/kg	LT 0.01	20.1
Manganese (Mn), mg/kg	LT 0.01	62.98
Cadmium (Cd), mg/kg	LT 0.01	LT 0.01
Zinc (Zn), mg/kg	0.03	230.4

LT : Less than
Results in mg/L where appropriate.
Test method variation : None
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories.

Head of Chemistry Section
For Al Hoty Stanger Laboratories

/rm

ص.ب ١٦٧٥٦ ، دبي ، ا.ع.م ، تليفون: ٣٤٧٢٢٠١ (٠٤) ، فاكس: ٣٤٧٢٧٢٧ (٠٤)
P. O. BOX 16756, DUBAI, U. A. E., TEL. : (04) 3472201, FAX : (04) 3472727
E-Mail : alhoty@emirates.net.ae

ISO 9002 CERTIFIED

AL HOTY - STANGER LABORATORIES
Independent Testing Laboratories
and Materials Consultants

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

TEST REPORT

CLIENT **SEVILLE PRODUCTS LTD. (AL QUOZ)**

ANALYSIS OF SLUDGE SAMPLE

Report No.	: DR-91523	Report date	: 02/09/2000
Sample No.	: DS-061639	Sampling method	: Composite
Name & designation of sampling officer	: AHS Rep. in presence of Seville Products Rep.		
Purpose of sampling	: Permit compliance	Sample container	: Plastic bag
Name & location of sampled premises	: Seville Products premises, Al Quoz	Sample appearance	: Black coloured sludge
Precise sampling Location Date Time	: Final Waste from treatment plant : 26/08/2000 : 1600 Hrs.	Test method	: 1. Standard Methods of Chemical Analysis, F.J. Welcher 2. Atomic Absorption Spectrometry 3. Standard Methods for the Examination of Water & Wastewater, APHA/AWWA/WEF, 20th Edition 4. Dubai Municipality's, E.P.S.S. T.G.L.#23
On-site treatment	: Sample transported in ice box	Test dates	: 26/08/2000 to 31/08/2000

Results :

PARAMETERS	RESULTS	
pH at 25°C (1:1 water extract)	8.74	
Conductivity at 25°C (1:1 water extract) ms/cm	3.85	
Moisture content, % by weight	33.3	
Organic matter at 550°C, %by weight	58.4	
Oils & grease (solvent extraction), mg/kg	2671	
Chemical Oxygen Demand (COD), mg/kg	113890	
Biochemical Oxygen Demand (BOD) (5 days @ 20°C)	32000	
METALS (ATOMIC ABSORPTION SPECTROMETRY)	Total Concentrate	Leachable Fraction
Copper (Cu), mg/kg	74.7	LT 0.01
Nickel (Ni), mg/kg	9.44	LT 0.01
Zinc (Zn), mg/kg	349	0.19
Chromium (Cr), mg/kg	32.9	0.44
Lead (Pb), mg/kg	22.5	2.22
Manganese (Mn), mg/kg	47.5	1.24
Cadmium (Cd), mg/kg	0.29	0.03

Results in mg/L where appropriate.
LT : Less than
Test method variation : None
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories.

Head of Chemistry Section
For Al Hoty Stanger Laboratories

AL HOTY-STANGER

ص.ب ١٦٧٥٦ ، دبي ، ا.ع.م.، تليفون: ٣٤٧٢٢٠١ (٠٤) ، فاكس: ٣٤٧٢٧٢٧ (٠٤)
P. O. BOX 16756, DUBAI, U. A. E., TEL. : (04) 3472201, FAX : (04) 3472727
E-Mail : alhoty@emirates.net.ae

L HOTY · STANGER LABORATORIES
ndependent Testing Laboratories
nd Materials Consultants

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

TEST REPORT

CLIENT **SEVILLE PRODUCTS LTD. (AL QUOZ)**

ANALYSIS OF SLUDGE SAMPLE

Report No.	:	DR-89046	Report date	:	08/08/2000
Sample No.	:	DS-059582	Sampling method	:	Composite
Name & designation of sampling officer	:	AHS Rep. in presence of Seville Products Rep.			
Purpose of sampling	:	Permit compliance	Sample container	:	Plastic bag
Name & location of sampled premises	:	Seville Products premises, Al Quoz	Sample appearance	:	Black coloured sludge
Precise sampling Location	:	Final Waste form treatment plant			
Date	:	02/08/2000	Test method	:	1. Standard Methods of Chemical Analysis, F.J. Welcher 2. Atomic Absorption Spectrometry 3. Standard Methods for the Examination of Water & Wastewater, APHA:AWWA:WEF: 20th Edition
Time	:	1700 Hrs.			
On-site treatment	:	Sample transported in ice box	Test dates	:	02/08/2000 to 07/08/2000

Results :

PARAMETERS	RESULTS
pH at 25°C (1:1 water extract)	8.10
Conductivity at 25°C (1:1 water extract) ms/cm	2.92
Moisture content, % by weight	89.4
Organic matter at 550°C, %by weight	8.24
Oils & grease (solvent extraction), mg/kg	412
Chemical Oxygen Demand (COD), mg/kg	144000
Biochemical Oxygen Demand (BOD) (5 days @ 20°C)	82000
METALS (ATOMIC ABSORPTION SPECTROMETRY)	
Copper (Cu), mg/kg	15.23
Nickel (Ni), mg/kg	2.92
Zinc (Zn), mg/kg	72.36
Chromium (Cr), mg/kg	7.13
Lead (Pb), mg/kg	6.40
Manganese (Mn), mg/kg	13.78
Cadmium (Cd), mg/kg	LT 0.01

Results in mg/L where appropriate.
LT : Less than
Test method variation : None
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories.

الحوطي ستانجر
AL HOTY-STANGER

Head of Chemistry Section
For Al Hoty Stanger Laboratories

/rm

ص.ب ١٦٧٥٦ ، دبي ، ا.ع.م. ، تليفون : ٣٤٧٢٢٠١ (٠٤) فاكس : ٣٤٧٢٧٢٧ (٠٤)
P. O. BOX 16756, DUBAI, U. A. E., TEL. : (04) 3472201, FAX : (04) 3472727
E-Mail : alhoty@emirates.net.ae

BSI REGISTERED FS 45701 UKAS 003
ISO 9002 CERTIFIED

Appendix 3

Dubai Municipality's Wastewater and Sludge Discharge Limits

(Source: Local Order No. 61/1991 on the Environment Protection Regulations in the Emirate of Dubai)

DM WASTE WATER & SLUDGE DISCHARGE LIMITS

PARAMETER Not to exceed	SEWER mg/l	LAND mg/l		MARINE mg/l	SLUDGE to land mg/kg
		Drip	Spray		
pH units	6 - 10	6.0 - 8.0	6.0 - 8.0	6 - 9	
Temperature	45 C / < 5 C ambient				
TDS	3000	1500	1000		
SS	500	50	10	25	
Turbidity				75 NTU	
B.O.D	1000	20	10	20	
C.O.D	3000	100	50	125	
O&G - Emulsified	150				
O&G	50	5	5	10 (on shore facility) 40 (off shore facility)	
Phenols	50	0.1	0.1	0.1	
Non-chlor.pesticides	5				
Ammonia as N	40	5	1	2.0	
Total N		50	30		
Org. N - Kiedhal		10	5		
Total organic carbon				75	
Total sulphates	500	200	200		
Sulphides as S	10	0.05	0.05	0.10	
Cyanides as CN	1	0.05	0.05	0.10	
Fluorides		1	1		
Chlorides		500	350		
Chlorine - residual	10			1.0	
Phosphorous (P)	30	20	20		
Detergents	30				
Total metals	10				
Aluminium (Al)		2	2		
Arsenic (As)	0.5	0.05	0.05	0.1	
Barium (Ba)		1	1		
Beryllium (Be)		0.1	0.1		
Boron (B)	2.0	2.0	2.0		
Cadmium (Cd)	0.3	0.01	0.01	0.05	30
Chromium (Cr)	1.0	0.1	0.1	0.50	1000
Cobalt		0.1	0.1		100
Copper (Cu)	1.0	0.2	0.2	0.50	1000
Iron (Fe)		2.0	2.0	2.0	
Lead (Pb)	1.0	0.5	0.5	0.10	1000
Magnesium (Mg)		100	100		
Manganese (Mn)	1.0	0.2	0.2		
Mercury (Hg)	0.01	0.001	0.001	0.001	10
Molybdenum (Mo)		0.01	0.01		20
Nickel (Ni)	1.0	0.2	0.2	0.10	200
Selenium (Se)		0.02	0.02	0.02	
Silver (Ag)	1.0			0.005	
Sodium (Na)		500	200		
Zinc (Zn)	2.0	5.0	2.0	0.10	1000
Faecal Coliforms- MPN/ 100ml		500	20	1000	
Gross Alpha/Beta activity Bq/l	10/100				

NB: This is only an extract of discharge limits specified in **draft new local Order** and does not cover all conditions of discharge

بلدية دبي

DUBAI MUNICIPALITY

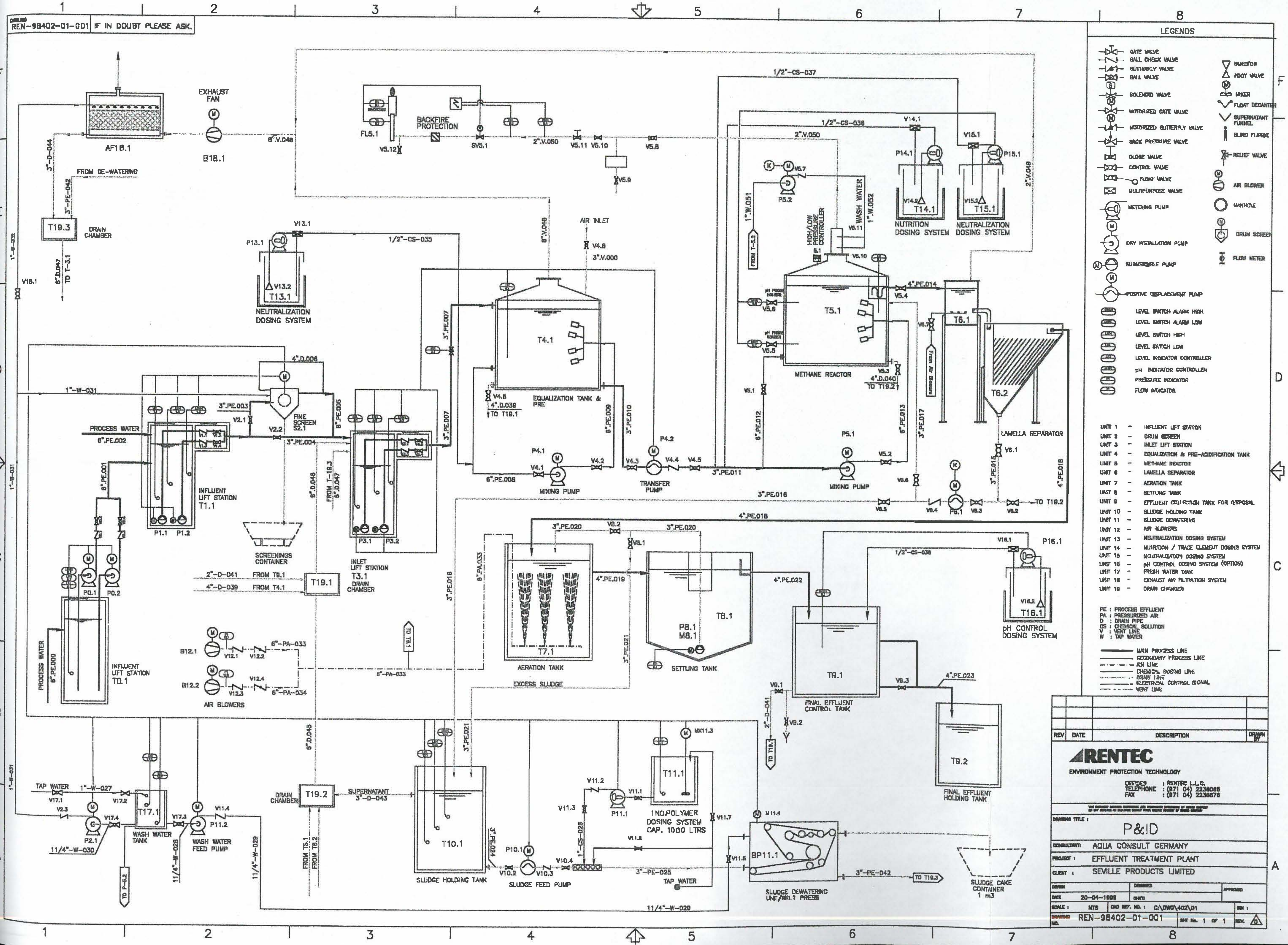
ANNEX III

LIMITS FOR DISPOSAL OF SLUDGE

ALL UNITS AS GRAMS PER TONNE		LONG TERM CUMULATIVE LOADING ON LAND
Parameter	Limits (not greater than)	Kgs. per Hectare
Cadmium	30	18
Chromium	1000	210
Cobalt	100	30
Copper	1000	46
Lead	1000	125
Molybdenum	20	5
Mercury	10	15
Nickel	200	78
Zinc	1000	170

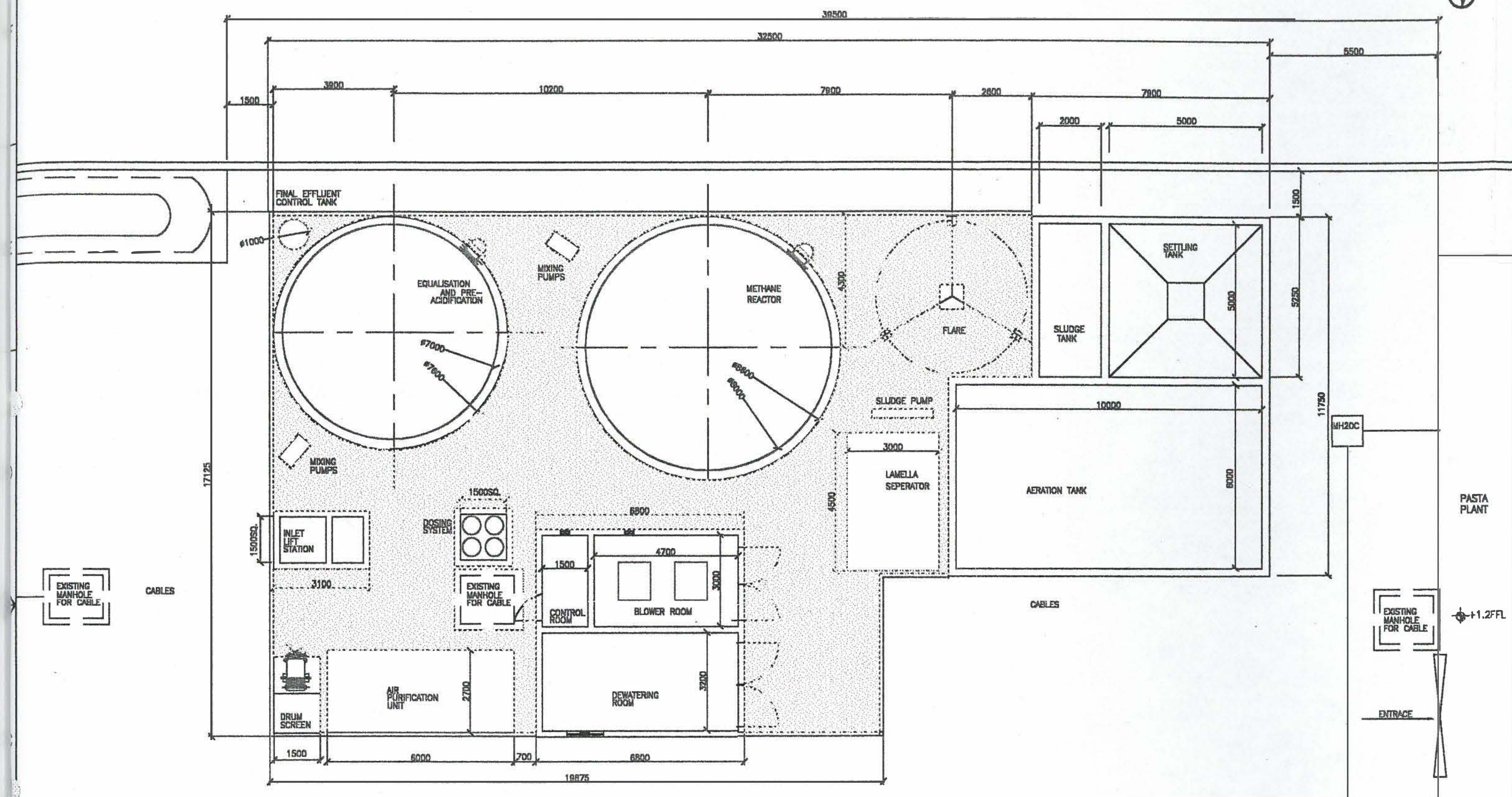
Appendix 4

Process Flow Diagram for Anaerobic/Aerobic Treatment at Seville Products Ltd.

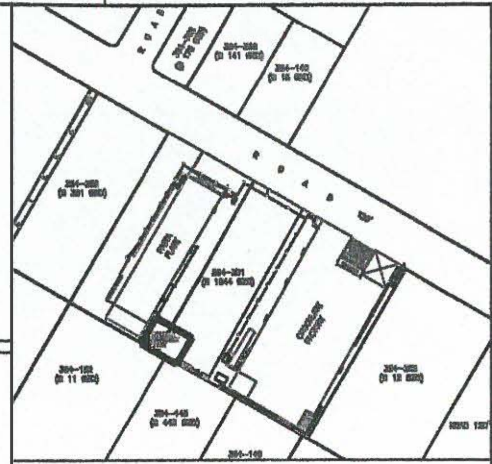


REN-98402-01-001 IF IN DOUBT PLEASE ASK.
LEGENDS
GATE VALVE
BALL CHECK VALVE
BUTTERFLY VALVE
BALL VALVE
SOLENOID VALVE
MOTORIZED GATE VALVE
MOTORIZED BUTTERFLY VALVE
BACK PRESSURE VALVE
GLOBE VALVE
CONTROL VALVE
FLOAT VALVE
MULTIPURPOSE VALVE
METERING PUMP
DRY INSTALLATION PUMP
SUBMERSIBLE PUMP
POSITIVE DISPLACEMENT PUMP
INJECTOR
FOOT VALVE
MIXER
FLOAT DECANTER
SUPERNATANT FUNNEL
BLIND FLANGE
RELIEF VALVE
AIR BLOWER
MANHOLE
DRUM SCREEN
FLOW METER
LEVEL SWITCH ALARM HIGH
LEVEL SWITCH ALARM LOW
LEVEL SWITCH HIGH
LEVEL SWITCH LOW
LEVEL INDICATOR CONTROLLER
pH INDICATOR CONTROLLER
PRESSURE INDICATOR
FLOW INDICATOR
UNIT 1 – INFLUENT LIFT STATION
UNIT 2 – DRUM SCREEN
UNIT 3 – INLET LIFT STATION
UNIT 4 – EQUALIZATION & PRE-ACIDIFICATION TANK
UNIT 5 – METHANE REACTOR
UNIT 6 – LAMELLA SEPARATOR
UNIT 7 – AERATION TANK
UNIT 8 – SETTLING TANK
UNIT 9 – EFFLUENT COLLECTION TANK FOR DISPOSAL
UNIT 10 – SLUDGE HOLDING TANK
UNIT 11 – SLUDGE DEWATERING
UNIT 12 – AIR BLOWERS
UNIT 13 – NEUTRALIZATION DOSING SYSTEM
UNIT 14 – NUTRITION / TRACE ELEMENT DOSING SYSTEM
UNIT 15 – NEUTRALIZATION DOSING SYSTEM
UNIT 16 – pH CONTROL DOSING SYSTEM (OPTION)
UNIT 17 – FRESH WATER TANK
UNIT 18 – EXHAUST AIR FILTRATION SYSTEM
UNIT 19 – DRAIN CHAMBER
PE : PROCESS EFFLUENT
PA : PRESSURIZED AIR
D : DRAIN PIPE
CS : CHEMICAL SOLUTION
V : VENT LINE
W : TAP WATER
MAIN PROCESS LINE
SECONDARY PROCESS LINE
AIR LINE
CHEMICAL DOSING LINE
DRAIN LINE
ELECTRICAL CONTROL SIGNAL
VENT LINE
AF18.1
EXHAUST FAN
B18.1
FROM DE-WATERING
T19.3 DRAIN CHAMBER
TO T-3.1
FL5.1
BACKFIRE PROTECTION
SV5.1
AIR INLET
T13.1 NEUTRALIZATION DOSING SYSTEM
T4.1
EQUALIZATION TANK & PRE
T5.1
METHANE REACTOR
HIGH/LOW PRESSURE CONTROLLER
WASH WATER
T14.1 NUTRITION DOSING SYSTEM
T15.1 NEUTRALIZATION DOSING SYSTEM
T6.1
T6.2
LAMELLA SEPARATOR
PROCESS WATER
FINE SCREEN S2.1
INFLUENT LIFT STATION T1.1
INLET LIFT STATION T3.1
SCREENINGS CONTAINER
MIXING PUMP
TRANSFER PUMP
T19.1 DRAIN CHAMBER
INFLUENT LIFT STATION T0.1
AIR BLOWERS
T7.1 AERATION TANK
EXCESS SLUDGE
P8.1 M8.1
T8.1
SETTLING TANK
T9.1
FINAL EFFLUENT CONTROL TANK
T9.2
FINAL EFFLUENT HOLDING TANK
T16.1 pH CONTROL DOSING SYSTEM
TAP WATER
T17.1 WASH WATER TANK
WASH WATER FEED PUMP
T19.2 DRAIN CHAMBER
SUPERNATANT
T10.1 SLUDGE HOLDING TANK
SLUDGE FEED PUMP
T11.1
1 NO.POLYMER DOSING SYSTEM CAP. 1000 LTRS
BP11.1
SLUDGE DEWATERING UNIT/BELT PRESS
SLUDGE CAKE CONTAINER 1 m3
REV DATE DESCRIPTION DRAWN BY
RENTEC
ENVIRONMENT PROTECTION TECHNOLOGY
OFFICES : RENTEC L.L.C.
TELEPHONE : (971 04) 2238085
FAX : (971 04) 2238678
DRAWING TITLE : P&ID
CONSULTANT : AQUA CONSULT GERMANY
PROJECT : EFFLUENT TREATMENT PLANT
CLIENT : SEVILLE PRODUCTS LIMITED
DATE 20-04-1999
SCALE : NTS
CAD REF. NO. : C:\DWG\402\01
DRAWING NO. REN-98402-01-001
SHT No. 1 OF 1

REN-98402-02-002 | IF IN DOUBT PLEASE ASK.



EFFLUENT TREATMENT PLANT



KEY PLAN
(SCALE NTS)

GENERAL NOTES:

1. ALL DIMENSIONS ARE IN mm.
2. ALL ELEVATION ARE IN METRES.
3. REFER DRG. NO. REN-98402-01-001 PROCESS FLOW DIAGRAM.
4. REFER DRG. NO. REN-98402-02-001 SITE SETTING LAYOUT
5. REFER DRG. NO. REN-98402-02-002 FOR PLANT LAYOUT.
6. REFER DRG. NO. REN-98402-03-001 FOR ARCHITECTURAL LAYOUT.
7. REFER DRG. NO. REN-98402-03-002 FOR ARCHITECTURAL SECTION & ELEVATION.
8. REFER DRG. NO. REN-98402-03-003 FOR ARCHITECTURAL DETAIL.
9. REFER DRG. NO. REN-98402-03-004 FOR STRUCTURAL LAYOUT.
10. REFER DRG. NO. REN-98402-03-005 FOR PLAN & SECTION OF MACHINERY ROOM.
11. REFER DRG. NO. REN-98402-03-006 FOR CIVIL DETAILS FOR AERATION/SETTLING/SLUDGE TANK.
12. REFER DRG. NO. REN-98402-03-007 FOR STRUCTURAL DETAILS SECTIONS FOR AERATION/SETTLING/SLUDGE TANK.
13. REFER DRG. NO. REN-98402-03-008 FOR STRUCTURAL SECTION DETAILS FOR INLET/INFLUENT LIFT STATION
14. REFER DRG. NO. REN-98402-03-009 FOR STRUCTURAL SECTION DETAILS.

REV	DATE	DESCRIPTION	DRAWN BY

ENVIRONMENT PROTECTION TECHNOLOGY

OFFICES : RENTEC L.L.C.
TELEPHONE : (971 04) 236086
FAX : (971 04) 236676

DRAWING TITLE : PLANT LAYOUT

CONSULTANT: AQUA CONSULT GERMANY

PROJECT : EFFLUENT TREATMENT PLANT

CLIENT : SEVILLE PRODUCTS LIMITED

DRAWN BY DATE	DESIGNED BY	CHK'D BY	APPROVED BY
SCALE : 1:75	CAD REF. NO.		SIZE :
DRAWING NO. REN-98402-02-002	SHT No. 1 OF 1		REV. 0

Appendix 5

Analysis of Wastewater Treatment in a Sequential Batch Reactor Plant

TY · STANGER LABORATORIES
endent Testing Laboratories
Materials Consultants

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

TEST REPORT

CLIENT **RENTEC**

ANALYSIS OF WASTE WATER

Report No.	: 32764		Report date	:	06/10/99
Sample No.	: 28497/8/9		Sample container	:	Plastic bottle
Name & designation Of sampling officer	: Rentec Representative		Sample appearance	:	Brown colour
Client's Description			Test methods	:	1) Standard Methods for the Examination of Water & Waste Water, APHA/AWWA/WEF, 19th Edition 2) Atomic Absorption Spectrometry
Purpose of sampling	: Quality assurance				
Name & location of sampled premises	: California garden (Gulf Food) JAFZ				
Precise sampling Location	: Lift Station				
Date & time of sampling	: 29/09/99 / 1000, 1200, 1400 Hrs.				
Sampling method	: Not specified		Test dates	:	29/09/99 – 06/10/99
On-site treatment	: Sample transported in ice box				

Results :

Parameters		Results
pH at 25°C		4.08
Total Kjeldahl Nitrogen		370
Total Phosphorous	(as P)	63
Ammonia Nitrogen		77
Oil & Grease	(Emulsified)	133
Chemical Oxygen Demand	(COD)	14293
Biochemical Oxygen Demand (5 days @ 20°C)	(BOD)	7933
Metals (Atomic Absorption Spectrometry)		
Iron	(Fe)	1.69
Copper	(Cu)	0.18
Nickel	(Ni)	0.14
Zinc	(Zn)	0.69
Chromium	(Cr)	LT 0.01
Lead	(Pb)	LT 0.01
Silver	(Ag)	LT 0.01
Aluminium	(Al)	LT 0.01
Molybdenum	(Mo)	LT 0.01
Manganese	(Mn)	0.14
Cadmium	(Cd)	LT 0.01

Results in mg/L where appropriate.
LT - Less Than
Test method variation : None
This test is not accredited by Dubai Municipality.
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories

Head of Chemistry Section
For Al Hoty Stanger Laboratories

m\/rm

ص.ب ١٦٧٥٦ ، دبي ، ا.ع.م ، تليفون : (٠٤) ٤٧٢٢٠١ ، فاكس : ٤٧٢٧٢٧ (٠٤)
P. O. BOX 16756, DUBAI, U. A. E., TEL : (04) 472201, FAX : (04) 472727
E-Mail : alhoty@emirates.net.ae

ISO 9002 CERTIFIED

9

OTY - STANGER LABORATORIES
pendent Testing Laboratories
Materials Consultants

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

TEST REPORT

LIENT

RENTEC

ANALYSIS OF WASTE WATER

port No.	:	17971	Report date	:	22nd June 1999
mple No.	:	14904	Date & time of sampling	:	16/06/99 – 1600 Hrs.
me & designation sampling officer	:	Rentec Rep. in presence of AHS Rep.	Sampling method	:	ASTM D 3370 : 1995
			Sample appearance	:	Hazy
rpose of sampling	:	Quality Assurance	Sample container	:	Plastic bottle
me & location of mpled premises	:	California garden (Gulf Food) JFZ	Test methods	:	Standard Methods for the Examination of Water & Waste Water, APHA/AWWA/ WEF, 19th Edition
ecise sampling ation	:	Feed tank			
n-site treatment	:	Sample transported in ice box	Test dates	:	16th – 21st June 1999

esults :

Parameters		Results
pH at 25°C		5.36
Total Suspended Solids	(TSS)	3560
Total Dissolved Solids at 180°C	(TDS)	1380
Dissolved phosphorous	(as P)	23
Total phosphorous	(as P)	24
Total kjeldahl nitrogen		74
Chemical oxygen demand	(COD)	7915
Biochemical oxygen demand (5 days @ 20°C)	(BOD)	2450

esults in mg/L where appropriate
est method variation : None
his test is not accredited by Dubai Municipality
his report relates only to the sample tested and shall only be reproduced in full and with the written approval
f AHS Laboratories.

Head of Chemistry Section
or Al Hoty Stanger Laboratories

AL HOTY-STAN...

mm

ص.ب : ١٦٧٥٦ ، دبـي ، الامـارات العـربيـة المتـحـدة ، تليفـون : ٤٧٢٢٠١ (٠٤) ، فـاكس : ٤٧٢٧٢٧ (٠٤)
P. O. BOX 16756, DUBAI, U. A. E., TEL. : (04) 472201, FAX : (04) 472727
E-Mail : alhoty@emirates.net.ae

TY - STANGER LABORATORIES
endent Testing Laboratories
Materials Consultants

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

TEST REPORT

RENTEC
ANALYSIS OF WASTE WATER

Report No.	: 18184	Report date	: 25.06.99
Sample No.	: 15085	Date & Time of sampling	: 17.06.99/ 1100 Hrs
Name & designation of sampling officer	: AHS Rep.in presence of Rentec Rep.	Sampling method	: ASTM D 3370 : 1995
Purpose of sampling	: Permit compliance	Sample container	: Plastic Bottle
Name & location of sampled premises	: California garden (Gulf Food) JAFZ	Sample appearance	: Hazy with suspended solids
Precise sampling location	: Feed water tank	Test methods	: Standard Methods for the Examination of Water and Waste Water APHA, AWWA, WEF. 19th Edn
On Site treatment	: Sample transported in ice box	Test date	: 17/06/99 - 25/06/99

Please find the test results :

Feed Water Tank

Parameters		Results
pH at 25 °C		7.32
Total Suspended Solids	(TSS)	3600
Total Dissolved Solids	(TDS)	1620
Dissolved Phosphorous as P		21
Total Phosphorous as P		28
Total Kjeldahl Nitrogen		46
Chemical Oxygen Demand	(COD)	5000
Biochemical Oxygen Demand (5 days @ 20°C)	(BOD)	2100

Test Method Variation : None
Results in mg/L where appropriate
This test is not accredited by Dubai Municipality.
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of the AHS Laboratories.

Head of Chemistry Section
For Al Hoty Stanger Laboratories

ALHOTY STANGER
الحوطي ستانجر

ص.ب : ١٦٧٥٦ ، دبـي ، الامـارات العـربيـة المتحدة ، تلفون : ٤٧٢٢٠١ (٠٤) ، فـاكس : ٤٧٢٧٢٧ (٠٤)
P. O. BOX 16756, DUBAI, U. A. E., TEL. : (04) 472201, FAX : (04) 472727
E-Mail : alhoty@emirates.net.ae

TY - STANGER LABORATORIES
endent Testing Laboratories
Materials Consultants

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

TEST REPORT

IENT

RENTEC

ANALYSIS OF WASTE WATER

ort No.	:	24168	Report date	:	31st July 1999
nple No.	:	20401	Date & time of sampling	:	20/07/99 – 1600 Hrs.
me & designation sampling officer	:	AHS Rep. in presence of Rentec Rep.	Sampling method	:	ASTM D 3370 : 1995
			Sample appearance	:	Brown colour
rpose of sampling	:	Permit compliance	Sample container	:	1 litre plastic bottle
me & location of npled premises	:	California Garden (Gulf Food) JAFZ	Test methods	:	1) Standard Methods for the Examination of Water & Waste Water, APHA/AWWA/ WEF, 19th Edition 2) Atomic Absorption Spectrometry
ecise sampling ation	:	SBR discharge			
-site treatment	:	Sample transported in ice box	Test dates	:	20th – 28th July 1999

sults :

SBR – FILTRATE

Parameters		Results
pH at 25°C		8.11
Total Suspended Solids (in supernatant sample)	(TSS)	24
Total Dissolved Solids at 180°C	(TDS)	2250
Total Dissolved Phosphorous		18
Total Phosphorous		18
Total Kjeldahl Nitrogen		126
Ammoniacal Nitrogen	(NH_3-N)	18
Residual Chlorines		LT 0.01
Chlorides		851
Sulphides	(S^{2-})	1.7
Phenolic compounds		ND
Dissolved oxygen	(DO)	ND
Chemical Oxygen Demand	(COD)	352
Biochemical Oxygen Demand (20°C @ 5 days)	(BOD)	28
Metals (Atomic Absorption Spectrometry)		
Copper	(Cu)	0.07
Zinc	(Zn)	0.86
Nickel	(Ni)	0.10
Manganese	(Mn)	0.15
Iron	(Fe)	0.65
Chromium	(Cr)	LT 0.01
Lead	(Pb)	LT 0.01
Cadmium	(Cd)	LT 0.01
Sodium	(Na)	566
Aluminium	(Al)	LT 0.01
Selenium	(Se)	LT 0.01
Arsenic	(As)	LT 0.01
Mercury	(Hg)	LT 0.01

Results in mg/L where appropriate; ND - Not Detected
Test method variation : None
This test is not accredited by Dubai Municipality
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories.

Christopher

Head of Chemistry Section
For Al Hoty Stanger Laboratories
/jm

الحوطي ستانجر
AL HOTY-STANGER

ص.ب ١٦٧٥٦ ، دبي ، ا.ع.م. ، هاتف ٤٧٢٢٠١ (٠٤) ، فاكس : ٤٧٢٧٢٧ (٠٤)
P. O. BOX 16756, DUBAI, U. A. E., TEL : (04) 472201, FAX : (04) 472727
E-Mail : alhoty@emirates.net.ae

BSI REGISTERED FS 45701 UKAS

OTY - STANGER LABORATORIES
pendent Testing Laboratories
Materials Consultants

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

TEST REPORT

IENT

RENTEC

ANALYSIS OF WASTE WATER

port No.	:	19620	Report date	:	24th July 1999
mple No.	:	16370	Date & time of sampling	:	27/06/99 – 1600 Hrs.
me & designation sampling officer	:	AHS Rep. in presence of Rentec Rep.	Sampling method	:	ASTM D 3370 : 1995
			Sample appearance	:	Brown colour
rpose of sampling	:	Permit compliance	Sample container	:	1 litre plastic bottle
me & location of mpled premises	:	California Garden (Gulf Food) JAFZ	Test methods	:	1) Standard Methods for the Examination of Water & Waste Water, APHA/AWWA/ WEF, 19th Edition 2) Atomic Absorption Spectrometry
ecise sampling cation	:	SBR discharge			
-site treatment	:	Sample transported in ice box	Test dates	:	27th June – 2nd July 1999

esults :

SBR – FILTRATE

Parameters		Results
pH at 25°C		6.77
Total Suspended Solids (in supernatant sample)	(TSS)	9
Total Dissolved Solids at 180°C	(TDS)	3820
Dissolved Phosphorous		22
Total Phosphorous		22
Total Kjeldahl Nitrogen		132
Ammonical Nitrogen	(NH_3-N)	22
Residual chlorine		LT 0.1
Chlorides		1560
Sulphides	(S^{2-})	1.8
Phenolic compounds		LT 0.01
Dissolved oxygen	(DO)	ND
Chemical Oxygen Demand	(COD)	360
Biochemical Oxygen Demand (20°C @ 5 days)	(BOD)	130
Metals (Atomic Absorption Spectrometry)		
Copper	(Cu)	0.06
Zinc	(Zn)	0.35
Nickel	(Ni)	0.13
Manganese	(Mn)	0.37
Iron	(Fe)	2.7
Chromium	(Cr)	0.17
Lead	(Pb)	LT 0.01
Cadmium	(Cd)	LT 0.01
Sodium	(Na)	1142
Aluminium	(Al)	LT 0.01
Selenium	(Se)	LT 0.01
Arsenic	(As)	LT 0.01
Mercury	(Hg)	LT 0.01

Results in mg/L where appropriate; ND - Not Detected
Test method variation : None
This test is not accredited by Dubai Municipality
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories.

Christopher

Head of Chemistry Section
For Al Hoty Stanger Laboratories
/jm

الحوطي ستانجر
AL HOTY-STANGER

ص.ب ١٦٧٥٦ ، دبي ، ا.ع.م ، تليفون : (٠٤) ٤٧٢٢٠١ ، فاكس : (٠٤) ٤٧٢٧٢٧
P. O. BOX 16756, DUBAI, U. A. E. TEL. (04) 472201, FAX : (04) 472727
E-Mail : alhoty@emirates.net.ae

BSI REGISTERED FS 45701 UKAS 003

OTY - STANGER LABORATORIES
pendent Testing Laboratories
Materials Consultants

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

TEST REPORT

CLIENT **RENTEC**

ANALYSIS OF WASTE WATER

Report No.	: 33105	Report date	: 06/10/99
Sample No.	: 28831	Sample container	: Plastic bottle
Name & designation of sampling officer	: Rentec Representative	Sample appearance	: Clear
Client's Description		Test methods	: 1) Standard Methods for the Examination of Water & Waste Water, APHA/AWWA/WEF, 20th Edition 2) Atomic Absorption Spectrometry
Purpose of sampling	: Quality assurance		
Name & location of sampled premises	: California Garden, (Gulf Food) JAFZ		
Precise sampling Location	: Dis charge collection tank		
Date & time of sampling	: 29/09/99 / 1600 Hrs.		
Sampling method	: Not specified	Test dates	: 30/09/99 - 05/10/99
On-site treatment	: Sample transported in ice box		

Results :

Parameters		Results
pH at 25°C		9.59
Colour	(Pt. Co Units)	10
Total Kjeldahl Nitrogen		1.2
Ammonia Nitrogen	(as NH_3–N)	LT 0.25
Oil and Grease		LT 1.0
Chemical Oxygen Demand	(COD)	88
Biochemical Oxygen Demand (5 days @ 20°C)	(BOD)	12
Metals (Atomic Absorption Spectrometry)		
Iron	(Fe)	2.45
Copper	(Cu)	0.06
Nickel	(Ni)	0.17
Zinc	(Zn)	0.67
Chromium	(Cr)	LT 0.01
Lead	(Pb)	LT 0.01
Silver	(Ag)	LT 0.01
Aluminium	(Al)	LT 0.01
Molybdenum	(Mo)	LT 0.01
Manganese	(Mn)	0.13
Cadmium	(Cd)	LT 0.01

Results in mg/L where appropriate.
LT - Less Than
Test method variation : None
This test is not accredited by Dubai Municipality
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories.

الحوطي ستانجر
AL HOTY-STANGER

Head of Chemistry Section
For Al Hoty Stanger Laboratories
/rm

ص.ب ١٦٧٥٦، دبي، ا.ع.م.، تليفون: ٤٧٢٢٠١ (٠٤)، فاكس: ٤٧٢٧٢٧ (٠٤)
P. O. BOX 16756, DUBAI, U. A. E., TEL. : (04) 472201, FAX : (04) 472727
E-Mail : alhoty@emirates.net.ae

8

...STANGER LABORATORIES
...ependent Testing Laboratories
and Materials Consultants

تبرات الحوطي ستانجر
...ات فحص مستقلة
...ـار ومواد

TEST REPORT

CLIENT **RENTEC**

ANALYSIS OF WASTE WATER

Report No.	:	63601	Report date	:	28/02/2000
Sample No.	:	043081	Sample container	:	Plastic bottle
Name & designation of sampling officer	:	Rentec Representative in presence of JAFZA	Sample appearance	:	Clear with light yellow c...
Client's Description			Sample received on time	:	1500 Hrs.
Purpose of sampling	:	Quality Assurance			
Name & location of sampled premises	:	Gulf Foods, California Garden	Test method	:	Standard Method for th... Examination of Water ... Waste Water, APHA/AWWA/WEF, 20th Edition
Precise sampling location	:	Final effluent			
Date & time of sampling	:	21/02/2000 / Not given			
Sampling method	:	Drain pipe	Test dates	:	21/02/2000 - 27/02/200...
On-site treatment	:	Sample transported in ice box			

Results :

PARAMETERS		RESULTS
pH at 25°C		8.32
Total Suspended Solids	(TSS)	7
Total Dissolved Solids at 180°C	(TDS)	800
Phosphates	(as PO_4-P)	4.2
Ammonia Nitrogen	(NH_3-N)	0.9
Total Kjeldahl Nitrogen	(TKN)	1.2
Chemical Oxygen Demand	(COD)	60
Biochemical Oxygen Demand (5 days @ 20°C)	(BOD)	6

Results in mg/L where appropriate.
Test method variation : None
This test is not accredited by Dubai Municipality
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories.

Christopher

Head of Chemistry Section
For Al Hoty Stanger Laboratories

/rm

الحوطي ستانجر
...OTY-STANGER

...GER LABORATORIES
...t Testing Laboratories
...terials Consultants

مختبرات الحوطي ستانجر
مختبرات فحص مستقلة
ومستشار ومواد

TEST REPORT

LIENT

RENTEC

ANALYSIS OF SLUDGE

;port No.	: DR-64947	Report date	:	07/03/2000
;mple No.	: DS-044278	Sample container	:	Plastic bottle
;me & designation ;sampling officer	: Rentec Representative	Sample appearance	:	Sludge mixed water
Client's Description		Test methods	:	Standard Methods for the Examination of Water & Wastewater, APHA/AWWA/WEF, 20th Edition
;rpose of sampling	: Quality assurance			
;ime & location of ;mpled premises	: California Garden Gulf Foods, JAFZ			
;ecise sampling ;ocation	: Sludge tank			
;ate & time of sampling	: 04/03/2000 / 1400 Hrs.			
;mpling method	: Not specified			
;n-site treatment	: Nil	Test dates	:	04/03/2000 – 07/03/2000

;esults :

PARAMETERS			RESULTS
Sludge content (% by weight)			25
Oil & Grease (mg/kg)			290
METALS (ATOMIC ABSORPTION SPECTROMETRY)			
Iron	(Fe)	mg/kg	48.55
Copper	(Cu)	"	4.94
Nickel	(Ni)	"	0.45
Zinc	(Zn)	"	11.03
Chromium	(Cr)	"	1.04
Lead	(Pb)	"	LT 0.01
Manganese	(Mn)	"	2.53
Cadmium	(Cd)	"	LT 0.01

LT : Less than
Results in mg/kg where appropriate.
Test method variation : None
This test is not accredited by Dubai Municipality
This report relates only to the sample tested and shall only be reproduced in full and with the written approval of AHS Laboratories

Head of Chemistry Section
For Al Hoty Stanger Laboratories

Vrm

Page 1 of 1

ص.ب ١٦٧٥٦ ، دبي ، ا.ع.م.، تليفون: ٣٤٧٢٢٠١ (٠٤) ، فاكس : ٣٤٧٢٧٢٧ (٠٤)
P. O. BOX 16756, DUBAI, U. A. E., TEL. : (04) 3472201, FAX : (04) 3472727
E-Mail : alhoty@emirates.net.ae

ISO 9002 CERTIFIED

E-Mail : alhoty@...

ملخص

- الهدف الأساسي من هذه الرسالة هو دراسة محطة لمعالجة مياه الصرف الصناعي يقوم باستخدام طريقة المعالجة البيولوجية اللاهوائية المستمرة و من ثم المعالجة الهوائية في معالجة المخلفات الصناعية السائلة والـــناتجة من مصنع لإنتاج الأغذية في إمارة دبي . وقد تم تصميم المصنع على تقنية المعالجة بالطريقة اللاهوائية تحت ظروف مناخ دولة الإمارات الحار بحيث يكون درجة حرارة الجو كافية على استمرارية التفاعلات المطلوبة .
- أثناء العملية اللاهوائية ، ينتج غاز بيولوجي يخزن في صهريج تجميع موصل بنظام حرق آلي، والحمأة الناتجة يتم تركيزها إلى ٢٥% محتوى المادة الصلبة الجافة وذلك بعد هضمها في الوحدة الهوائية .
- لإجـــراء هـــذا الدراسة , تم أخذ عينات من المياه والحمأة لتحليلها من الخطوط الداخلة لمحطة المعالجة والخارجة منها على مدار العام لدراسة تأثير المناخ على كفاءة أداء المعالجة . وقد تم تحليل هذه العينات فـــي المعامل المركزية بالجامعة وبعض العينات أرسلت إلى مختبرات خاصة بمدينة دبي لإجراء تحاليل أخرى .
- النـــتائج أثبتت أن الطريقة البيولوجية اللاهوائية ذات الطورين تعمل بكفاءة تحت الظروف المناخية لدولة الإمـــارات العربـــية المتحدة، وإنها طريقة مناسبة لمنطقة الشرق الأوسط حيث إنها لا تحتاج إلى حرارة إضافية لإتمام عملية المعالجة .
- وقورنت هذه الطريقة مع طرق المعالجة الأخرى المستخدمة في المناطق الصناعية بدبي والدراسة أثبتت كفـــاءة أداء هـــذه الطـــريقة مقارنة بالسبل الأخرى في معالجة المخلفات الصناعية السائلة المحتوية على تراكيز عالية من الملوثات العضوية .

معالجـــة ميـــاه الصـــرف الصنـــاعـــي النـــاتجـــة مـــن مصنـــع غـــذائـــي تحـــت الظـــروف المنـــاخيـــة

رســـالة مقدمـــة مـــن

سـعيـد محـمـد ولي عبـدالله كـرمسـتـجي

بكالوريوس تكنـــولـــوجيـــا التحكـــم في التلـــوث البيئـــي
جامعـــة كارولاينـــا الشماليـــة - الـــولايـــات المتحـــدة (١٩٩٦)

استكمـــالاً لمتـــطلبـــات الحصـــول علـــى درجـــة الماجســـتير
فـــي
علـــوم مـــوارد الميـــاه

جامعـــة الإمـــارات العـــربيـــة المتحـــدة
عمـــادة الـــدراســـات العليـــا
يـــونيـــو ٢٠٠٣